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EIELSON AIR FORCE BASE
ALASKA

ENVIRONMENTAL RESTORATION PROGRAM

OPERATIONS & MAINTENANCE MANUAL

SITE 48 TREATABILITY STUDY SYSTEM

FINAL

DECEMBER 1993

AQM01-03-0550

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NOTICE

This operating manual has been prepared for the U.S. Air Force by Jacobs Engineering Group Inc. for the purpose of starting up, operating, and maintaining the Site 48 Treatability Study process system under the Air Force Installation Restoration Program (IRP). The limited objectives of this operating manual and ongoing nature of the IRP, along with the evolving knowledge of site conditions and chemical effects on the environment and health, must be considered when evaluating this operating manual. Subsequent facts may become known that may make this manual premature or inaccurate. Acceptance of this operating manual in performance of the contract under which it is prepared does not mean that the U.S. Air Force adopts the procedures or other views expressed herein. These views and procedures are those of the contractor only and to not necessarily reflect the official position of the U.S. Air Force.

JE

JACOBS ENGINEERING GROUP INC.

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10 December 1993

Mr. Mike McGhee
Alaska Restoration Team Chief
AFCEE/ESRU
8001 Inner Circle Drive, Suite 2
Brooks Air Force Base, Texas 78235-2358

Subject: **Contract No. F33615-90-D-4009**
Delivery Order No.4
Eielson AFB Vacuum Extraction/Flare System
Eielson AFB, Alaska
Final Operations and Maintenance Manual

Dear Mr. McGhee:

Enclosed is the Final Operations and Maintenance (O&M) Manual including appendices detailing the relevant engineering drawings and design data used to size and operate the treatability system. We incorporated the review comments on the Draft O&M Manual submitted by Lt Col Miller and the Eielson AFB Civil Engineering staff.

As of today, Allied Flare still has not sent us the electrical schematic for the "blue warning light" modification they made to the flare. When we receive it we'll include this small wiring diagram at Appendix C, Section 7, Plate 31199_1, Electrical System. I'll send you and all the individuals listed below either a new plate diagram or an adhesive section to be mounted on the plate diagram detailing the blue warning light electrical schematic.

Sincerely,
JACOBS ENGINEERING GROUP INC.

Ronald E. Hergenrader, PE, CIH, DEE
Manager of Projects

cc: Mr. Al Hinchee, Eielson AFB (three copies)
Lt Col Ross Miller, AFCEE (one copy)
Mr. Marty Faile, AFCEE (one copy)
Mr. Mike McGhee, AFCEE (two copies)
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OPERATIONS AND MAINTENANCE MANUAL

SITE 48 TREATABILITY STUDY SYSTEM

EIELSON AIR FORCE BASE
ALASKA

NOVEMBER 1993

100% Recycled

OPERATIONS AND MAINTENANCE MANUAL

SITE 48 TREATABILITY STUDY SYSTEM

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LIST OF ACRONYMS

AFB	Air Force Base
BOD	Biochemical Oxygen Demand
BTU	British Thermal Unit
CFR	Code of Federal Regulations
gpm	Gallons per Minute
Hg	Mercury
LEL	Lower Explosive Limit
O&M	Operations and Maintenance
psi	Pounds per Square Inch
PVC	Polyvinyl Chloride
scfm	Standard Cubic Feet per Minute
TPH	Total Petroleum Hydrocarbons
TRPH	Total Recoverable Petroleum Hydrocarbons
VOC	Volatile Organic Compound
mg/L	Milligrams per Liter

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1.0 INTRODUCTION

1.1 GENERAL INFORMATION

This manual provides a single source reference on the operation and maintenance of the Eielson Air Force Base (AFB) Site 48 Treatability Study system. The Treatability Study investigates the technical feasibility and efficiency of removing two sources of petroleum-derived dissolved constituents. The two sources that will be removed are (1) liquid petroleum product on top of the water table and (2) residual petroleum product in the vadose zone. A vacuum pump will remove the liquid petroleum product from the top of the water table while at the same time oxygenate the soil by pulling air through the vadose zone. Increasing the oxygen in the soil can enhance microbial degradation of the residual total petroleum hydrocarbons (TPH) in the soil pores.

A vacuum pump is connected to a series of draw-down tubes that are placed within nine extraction well casings. The open end of the draw-down tube is placed at the interface of the weathered product and water table within the well casing. With the tip of the draw-down tube located at, or slightly above the interface, the weathered product is removed, but very little, if any, groundwater is extracted. An important objective of the Treatability Study is to minimize pumping groundwater from Site 48.

As a vacuum is applied at the end of the draw-down tube, a vacuum is also created within the perforated extraction well casing. The influence of the vacuum spreads radially from the well casing. The distance an effective vacuum can be established within the soil around a specific well is termed the "radius of influence." The actual operating radius of influence depends on a number of site-specific soil parameters (e.g., particle size distribution, air permeability, moisture content, clay content, etc.). In fact, the radius of influence can vary between vacuum wells within the same general area or in different directions from a specific well. In general, ambient air is pulled through the soil within the radius of influence generated around each vacuum well.

The liquid product removal rate depends on the rate at which product enters each perforated well casing. The Treatability Study system is not a cone-of-depression pumping system, where the product flows to a well casing because of a difference in the potentiometric head (i.e., potentiometric head is lower at the cone-of-depression well). As stated, this system will not establish a cone-of-depression because very little, if any, groundwater is extracted by the draw-down tube. Therefore, the product flows to the vacuum well because of a difference in hydrostatic pressure.

As the system operates, there is two-phase flow (i.e., air and liquid) in the draw-down tube and vacuum header piping to the vacuum pump. The two-phase flow rate at each well is manually controlled at the wellhead and may be changed to achieve a desired liquid product removal rate dictated by geological parameters and vacuum well response.

The Treatability Study system includes nine vacuum wells; vacuum header piping that connects the vacuum wells to the liquid ring vacuum pump; two, two-phase flow separation tanks; an air/water heat exchanger; a flare with a propane spike gas; pilot ignitor and supply tank; and an oil/water separator. Interconnecting piping, ancillary valves and pumps, electrical power/control units, instrumentation, and piping to transport the effluent groundwater to an onsite above-ground tank. The flare is used to thermally destruct the volatile organic compounds (VOCs) contained in the exit air from the liquid ring vacuum pump. Engineering drawings EIE-100-001 through -003 (contained in Appendix A) show the well locations, equipment layout, piping, instrumentation, and process flow.

Effective operation of the system requires properly installed system components coupled with consistent and routine operating and maintenance programs. Initial check out of system components to ensure proper operation is included in Section 3.0, Start-Up. A start-up checklist is provided in Appendix B. Other sections of this manual include instructions for system monitoring, operations, and maintenance.

The maintenance schedules specified in this manual are based on experience with this unit and similar systems. The frequency of the maintenance tasks, as with any system of this type, will depend on site-specific conditions. For example, the vacuum wells must be checked weekly by operating personnel to ensure proper liquid product is removed (i.e., minimal groundwater extraction recovery rates). Recovery rate and fluid level data from the vacuum wells must be measured and recorded so operating problems can be quickly detected and corrected. A vacuum well gauging log form is provided for this purpose (Appendix B).

The operator may be required to measure water levels in a few groundwater monitoring wells near the vacuum wells, measure radius-of-influence vacuum, record fluid level and vacuum data, and retain the data for analysis. An example of the monitoring well gauging log is contained in Appendix B.

All data should be reviewed by the field operating personnel on a weekly basis for completeness and accuracy and to determine if changes are needed in the system operation. Accumulated data and information should then be submitted to the immediate supervisor.

1.2 PROCESS DESCRIPTION

Engineering Drawing EIE-100-001 is the pipe and process layout drawing and EIE-100-002 is the piping and instrumentation diagram for this system. The drawings will be useful to the operator for understanding the process and troubleshooting the system. To assist the user of this manual, the equipment numbers shown on the P&ID drawing are indicated as bracketed numbers [XX.XXX] following the equipment callout in the text.

The vacuum wells (VEW-1 through -9) recover liquid product from the top of the water table. A little groundwater may be extracted along with the liquid product. Each well has a draw-down tube inserted within the well casing. The operator must place and maintain the tip of the draw-down tube within the well casing slightly above the interface between the liquid product and water table. The wellhead is constructed so the depth of the draw-down tube can be adjusted. Two-phase flow (i.e., air and liquid) is pumped through the header pipe, which connects the vacuum wells to the vacuum pump. The liquid at the vacuum wells is a mixture of weathered petroleum product and groundwater.

Air flow rate at each wellhead is adjustable with a 4-inch manual valve. A pressure gauge is located on each well head. A sight-flow glass is provided to assist in locating the draw-down tube at the proper interface depth in the well.

1.2.1 Knock-out Tank [13.001]

The air and liquid mixture pumped from the vacuum wells will flow to a knock-out tank immediately upstream of the vacuum pump [02.001]. The purpose of the knock-out tank is to separate the liquid (i.e., fuel product and groundwater) from the air. The liquid is pumped from the knock-out tank by the oil/water drain pump [01.001] rated at 30 gallons per minute (gpm) to an oil/water separator [09.001].

1.2.2 Oil/Water Separator [09.001]

The fuel-contaminated liquid is pumped from the knock-out tank to the oil/water separator, which separates the weathered fuel product from the groundwater. The oil/water separator is a horizontal vessel with three sections and vented inlet and outlet connections. The vents extend above the unit so that once filled, the separator will remain filled until it is drained or pumped down. The mixed fuel product/water inlet stream enters one end and flows through a stack of parallel corrugated plates into the center main separation section where the product and water separate. Corrugated parallel plates contact the flowing fluid mixture and assist in coalescing the smaller hydrocarbon particles to enhance the separation process.

In the center section, fuel product collects on the water surface and increases in thickness. The fuel product flows automatically from the separator as both fluid levels (water and product) increase. Materials heavier than water will collect in the bottom as sludge and must be flushed periodically from the separator. Separated water flows through a series of baffles into the third section. The separator effluent gravity flows to the oil/water separator overflow tank [09.003]. The effluent from the overflow tank is pumped by the separator drain pump [01.003] to an aboveground holding tank. The effluent and total recoverable petroleum hydrocarbons (TRPH) contaminated water is then pumped through a carbon adsorption system and discharged to the base sewer.

The fuel product removed from the oil/water separator flows by gravity into a 55-gallon waste oil storage drum. When a drum is 80 percent full, the operator must replace the drum with an empty one. The full waste oil drum must be removed from the site, and disposed of in accordance with Eielson AFB regulations.

Under normal operations, the separation of product and water should occur where the free product concentration in the effluent water is not greater than 15 milligrams per liter (mg/L). Periodically, an oil/grease grab sample should be taken on the effluent water and analyzed to determine the effectiveness of the oil/water separator.

1.2.3 Vacuum Pump [02.001]

The air from the knock-out tank [13.001] flows to the vacuum pump. The vacuum pump is a "liquid ring type pump." A liquid ring pump is used in this application because the VOC concentration in the air from the vacuum wells may be at a combustion level exceeding the lower explosive limit (LEL) for an air/fuel vapor mixture. A liquid ring pump provides a water seal to cool the pump and to prevent a spark from being produced by metal rubbing on metal. The potential for an explosion is less with a liquid ring pump, when the LEL may be exceeded.

Recycled seal water cools the pump and mixes with the discharge air as the water flows through the vacuum pump at the rate specified in the Performance Data Sheet (see Appendix C).

1.2.4 Sealing Liquid Separator Tank [13.002]

The exit air from the vacuum pump contains the pump's seal water, as a vapor, when it flows into the separation tank. In the separator tank, the seal water is separated from the exit air. The seal water is pumped [01.002] from the separator tank through an air/water heat exchanger [11.001]. Ambient air cools the seal water so it can be recycled back to the vacuum pump [02.001].

The seal water temperature is controlled between 80 and 100 degrees Fahrenheit. The interior of the enclosure ("bluebox") containing the vacuum pump, process vessels, and oil/water separator is controlled between 50 and 90 degrees Fahrenheit. During the summer months, ambient air will be pulled into the enclosure and through the air/water heat exchanger [11.001] and discharged outside. During the winter months it is important to maintain a nonfreezing temperature within the bluebox enclosure. Therefore, the cooling air will not be discharged outside the bluebox after it passes through the heat exchanger. The cooling air will be returned to the bluebox to keep the interior warm.

1.2.5 Flare

The VOC concentration in the exit air from the air/seal water separator tank may exceed the LEL for a fuel/air mixture. The exit air flows to a propane tip pilot and flare on top of the flare tower where the VOCs are thermally destroyed. The flare is designed for smokeless operation and meets the requirements of 40 Code of Federal Regulations (CFR) 60.18, Performance Standards.

When the Treatability Study system first begins to operate, there are sufficient British Thermal Units (BTUs), combustible product, and oxygen in the exit air to operate as a smokeless system. However, as product is removed from groundwater the VOC concentration in the air will decline along with the BTU value. At a critical VOC concentration, propane must be added to the exit air to maintain a combustible mixture.

1.2.6 Injection Piping

After the VOC concentration in the exit air declines to an equilibrium level, the exit air from the vacuum pump may be injected back into the vadose zone. The exit air will be warmer and have a higher moisture content than the normal ambient air. This combination, along with the increased oxygen concentration, should significantly increase the microbial degradation rate in the soil.

The vacuum extraction wells are located in two sets of well fields (see Drawing EIE-100-001, Appendix B). One well field has four vacuum wells. The other well field has five vacuum wells. The pipe that transports the exit air from the air/seal water separator has a connection pipe upstream from the main line shutoff valve. When this main line shutoff valve is closed and one of the valves in the connecting line is open, the exit air will flow to the well field controlled by the connecting line valve. There is a shutoff valve in the vacuum well header downstream of the point where the connecting line enters the header. This header valve will be closed when the connecting line valve is opened. The wells that were previously used to draw a vacuum can now be used to inject the exit air into the vadose zone.

With the proper valves closed and opened, air pumped to the vacuum pump from one well field can be injected into the other well field. VOC and LEL measurements made in the exit air piping will assist the operator in determining when the exit air can be injected into the vadose zone of the other well field.

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2.0 OPERATION

2.1 OPERATING PHILOSOPHY

The design/operating philosophy for the Treatability Study system is controlled with a manual start and an automatic shutdown if a malfunction occurs. The system must be manually started following electrical power failures and/or system malfunctions. Malfunctions that will automatically shut down the system include the following:

- seal water circulating pump [01.002] malfunction;
- low seal water level;
- high seal water temperature;
- high liquid level in the knock-out tank [13.001];
- pressure greater than 6 pounds per square inch (psi) at the exit side of the sealing liquid separator tank [13.002];
- electrical power failure; and
- blue warning light.

When any one of the above malfunctions occurs, the power to the vacuum pump [02.001] and other system components will be turned off automatically.

2.2 SYSTEM CONTROL

2.2.1 Wellhead

A header valve is located at each wellhead immediately upstream of the draw-down tube. The wellhead valve will control the flow rate at each wellhead. If the operator decides a certain well should not be operated, the operator can close the specific wellhead valve and isolate that vacuum well from the system.

The end of the draw-down tube may be placed at any depth within the well casing. The objective is to place the tip just above the interface between the floating petroleum product and the water in the casing. If there is no petroleum product in the well, there is no need to have a draw-down tube in that specific well. Locating the end of the draw-down tube is described in the Section 3.0, Start-up.

The operator must periodically check the depth of the water in each casing. This is determined by system operating experience. When operation first begins, daily checks may be required. As operation progresses, weekly or monthly checks may be adequate. There is a sight glass on the exit pipe at each wellhead that the operator should monitor during daily inspections as a quick check to ensure that liquid is being removed from the well. A sample can be collected from a sample valve at each wellhead to visually check for floating fuel product in the water.

The water depth in the well will be checked by first closing the header valve so there is no vacuum being pulled by the pump. There may still be a measurable vacuum at the wellhead because of the radius of influence of a nearby vacuum well. An oil/water interface probe should be lowered through a port in the wellhead cap after removing the plug. The operator must measure the depth to petroleum product, if any, and the depth to the water. The operator must remember that the water column in the well casing will rise up within the casing when a vacuum is applied to the well by the pump. Therefore, the end of the draw-down tube may not be at this exact measurement depth.

It is important that the amount of liquid extracted during the operation of the system is kept around 15 gpm, because this is the optimum flow rate for the oil/water separator. Through operating experience, the operator will establish the optimum depth of the draw-down tube.

It should be noted that a visual check may indicate that there is no liquid being pulled out of a specific well. The inflow of petroleum product into a specific well will be relatively slow compared with the groundwater flow if groundwater is extracted from the well. If there is petroleum product in the well when the operator first checks the product thickness but there is no visual product in the effluent, the operator may have to lower the end of the draw-down tube closer to, or even into, the water. Before the end of the tube is lowered into the water, field VOC and LEL instrument measurements should be made on the effluent from the well. Elevated measurements, compared with a well without any petroleum product, mean that the fuel product is being removed, but the amount of liquid in the air effluent is so small that it is not visually detectable.

2.2.2 Knock-Out Tank [13.001]

If more than 30 gpm of liquid are being pulled from all of the vacuum wells, the liquid level in the knock-out tank will rise to an unsafe level and trigger a system shutdown.

There is a butterfly valve on the inlet side of the knock-out tank. This valve must be in the open position at all times when the system is operating. If, for some reason, this valve is closed during nonoperating conditions, it must be opened before the system is restarted.

There is another valve on the knock-out tank that will allow ambient air to enter the tank when opened. The operator should open this valve when less vacuum is desired at all of the wellheads. This valve should also be opened before the system is shut down for maintenance because the downstream components must be purged with ambient air before any maintenance activities occur. Depending on operating experience, the valve should be open when the system is restarted after every shutdown and then gradually closed when the vacuum pump [02.001] achieves its normal operating condition.

In addition, there is a solenoid-operated valve on the knock-out tank that opens to allow ambient air into the system when the oil/water drain pump [01.001] is turned on.

There are several liquid level controllers in the knock-out tank. The normal high operating level controller turns the oil/water drain pump [01.001] on. This pump will transfer the liquid from the knock-out tank to the oil/water separator [09.001]. The normal low operating level controller turns the oil/water drain pump off.

2.2.3 Vacuum Pump [02.001]

There are several system malfunction switches and regulators controlling the vacuum pump. The pump and system will be shut down if any of the following situations occur:

- the outlet pressure of the pump is greater than 6 psi;
- the seal (cooling) water temperature is too high;
- high liquid level in knock-out tank [13.001]; and
- high level in the sealing liquid separator tank [13.002].

The vacuum pump is rated at 500 standard cubic feet per minute (scfm) at 15 inches of mercury (Hg). It will not operate at this capacity at all times. When the knock-out tank solinoid valve is open, 7.5 inches of Hg is required. When this valve is open, flare operation is disrupted. Pressure gauges are located on the pump inlet and outlet side.

The maximum operating discharge pressure will be determined through experience with operating the system. When the system is started, the maximum discharge malfunction control pressure is set at 6 psi. The vacuum pump can operate at higher pressures, but the flow rate will be less.

2.2.4 Seal Water Circulating Pump [01.002]

The sealing liquid separator tank [13.002] on the downstream side of the vacuum pump is designed to separate the seal (cooling) water from the exit air. With the proper quantity of sealing water supplied to the vacuum pump [02.001], the temperature rise across the vacuum pump should be limited to approximately 10 degrees Fahrenheit. If the air/water heat exchanger [11.001] malfunctions, the seal water temperature rises too high, and the system will automatically shut down.

During the summer months the air/water heat exchanger fan may operate most of the time. The shutters will be opened or closed to control the inside temperature. During the winter months the temperature of the air within the enclosure will be controlled at 50 degrees Fahrenheit by the air heater electric [11.002]. During winter operations, the shutters will be closed most of the time, and the exchanger cooling air directed back into the enclosure.

The seal water is recycled, but there will be some loss because of evaporation. There is a make-up water tank [09.002] mounted on the top side of the sealing liquid separator tank [13.002]. The operator must fill this small tank with water each day. The make-up water is gravity fed into the separator tank through a water level control valve. There is a hose-bib connection to the base water supply. This must be connected and turned on before the system is operating.

2.2.5 Flame Arrestor [36.001]

There is a flame arrestor (an explosive safety device) on the outlet pipe connected to the flare. If for some reason a flame starts to back flash from the flare tip, the flame arrestor will stop the flame from reaching the vacuum system.

2.2.6 Flare

The flare is designed to operate automatically. In August 1993, the flare was modified to use propane as a spike gas to ensure that the exit air from the vacuum system remains combustible when the VOC concentration drops below combustible levels. The propane pilot uses as electric spark ignitor to automatically ignite at startup or if the pilot is snuffed out during operation when combustible VOC levels decrease.

The system operator should check LEL and VOC concentrations in the exit air daily. During initial operation, the propane spike gas may not be needed because of high LEL and VOC concentrations in the exit air. The system is designed to operate above LELs. However, as the system operates, the VOC concentrations in the exit air may decrease to the point where the air is not combustible. The propane spike gas should be turned on at that time. Also, exit air which is noncombustible may be pumped back to the vacuum wells for injection into the vadose zone for bioventing purposes.

2.2.7 Oil/Water Separator [09.001]

The oil/water separator should be filled with water at all times for proper operation.

Liquid from the knock-out tank [13.001] is pumped [01.001] to the top side of the oil/water separator and flows over the velocity head diffusion baffle, which is a heavy metal plate, inclined downward at a 45-degree angle.

Influent suspended solids settle out and are collected behind the sludge baffle plate mounted on the separator floor. A drain valve for accumulated sludge is located on the outside of the bluebox enclosure.

Lighter density oil droplets and concentrated oil slugs rise immediately to the surface of the separator. The remaining oily water mixture then passes through an inclined arrangement of parallel corrugated plates. These corrugated parallel plates improve the separation efficiency of separation by enlarging the effective separation surface area. The corrugated plates are stacked upward at a 22.5-degree angle and are spaced 3 inches apart to prevent fouling. Under laminar flow conditions, buoyancy forces cause oil droplets to rise and coalesce into sheets of oil on the underside of each of the plates. The sheets of oil move up the surfaces of the plates and finally break loose at the top to form large globules that rapidly rise through the separating chamber to the surface. During operation, the maximum distance that an oil particle has to rise for effective removal is the 3 inches between the plates.

The oil/water separator is equipped with an oil skimmer that can be manually adjusted to drain off precisely the amount of oil desired. As the free-floating oil enters the skimmer, it flows by gravity out of the skim pipe, through the wall of the separator, and into a waste oil drum for accumulation and subsequent removal by base personnel. The operator must check the free-floating oil level in the drum every day.

For automatic skimming, the skim edge must be set slightly above the maximum water level when there is no free-floating oil in the oil/water separator and there is flow into the separator (about 0.5 inch). This setting will ensure no water will be skimmed off into the waste oil storage drum. The oil/water separator is currently setup for this contingency.

When water flow is less than 30 gpm through the separator, a thick product level will accumulate before skimming takes place because typical floating oil layers vary between 80 percent below and 20 percent above the original water line. However, most of the oil will be removed during maximum flow conditions through the separator.

The water collected from the separator flows by gravity to the oil/water separator overflow tank [09.003] connected to the separator drain pump [01.003]. Level controls in the tank signal the pump to transfer water to an above-ground tank where it is stored. Before the water is discharged to the base sewer system, it must be passed through a carbon adsorption process.

2.3 WINTERIZATION

To provide freeze protection during the winter, electric heat tracing is wrapped on all exposed header piping from the vacuum wells to the vacuum pump enclosure. All thermostats are ambient-sensing. Thermostats should be set at approximately 50 degrees Fahrenheit.

The interior air of the bluebox enclosure must be maintained above 50 degrees Fahrenheit. There are no immersion heaters in any of the process vessels (i.e., knock-out tank, separator tank, and oil/water separator) because they are all contained within the temperature-controlled enclosure.

When the system is shut down for an extended period of time during the winter months, the header pipes must be purged with ambient air. This is accomplished by opening the vent valve on the tee to which the draw-down tube is connected at each wellhead. Also, all the pipes, pumps, and knock-out and separation tanks in the enclosure should be drained of any liquid and filled with antifreeze. See Section 5.0 for specific procedures.

3.0 START-UP

3.1 INITIAL START-UP

The following are step-by-step procedures for initial start-up or start-up after extended downtime (greater than two weeks). It is recommended that these procedures be followed even though the system has been down only for routine maintenance. These checks can reveal minor problems, such as leaks, before they become major ones. In addition, a start-up checklist is provided in Appendix B. The operator should perform the following activities:

1. Notify the Civil Engineering Environmental department.

2. Arrange to deliver some empty waste oil drums.

3. Measure the depth to water in each well, including the depth to the petroleum product and the thickness of any petroleum product in each well.

4. Fill the make-up water tank [09.002] to ensure that extra sealing water for the vacuum pump [02.001] is available. To do this, connect the water supply hose to the hose bib connection directly under the make-up tank. Open the hose bib valve and the valve on the outlet side of the make-up tank (this valve is on the outside of the vacuum unit). Turn on the water supply. When the make-up water tank is full, close the outlet valve on the tank, but leave the water supply and the hose bib valve below the tank open. Open all doors to the blue box so that the system can be ventilated and inspected while in operation.

5. Fill the oil/water separator [09.001] with water to a level 1 inch below the water discharge line, if necessary.

6. Check the operation of the vacuum pump [02.001] in accordance with the operation and maintenance (O&M) manual provided by the manufacturer (Appendix C).

7. Raise the end of each draw-down tube 4 feet above the top of the liquid level in the well casing. Open each well header valve.

8. Open all the valves going to the knock-out tank [13.001].

9. Configure valves on header piping to draw air from well to vacuum unit.

10. Open the valve that allows the exit air to flow to the flare.

11. Check the flare system in accordance with the O&M manual provided by the manufacturer (Appendix C). Initial startup will require drying out the ceramic on the ignitor. This can be accomplished with a propane or acetylene torch.

12. Energize all main circuit breakers at the control panel and turn on the flare pilot unit and induction fan.

13. Start the vacuum pump [02.001] and operate it with the draw-down tubes raised.

14. Conduct a walk-around inspection of all piping runs and valves to make sure there are no vacuum leaks. Check all valves, pipes, and equipment housed within the bluebox enclosure for leaks. All positive pressure lines should be checked with a field VOC and/or LEL measuring instrument. Check operation of flare and adjust spike propane valve as required.

15. Measure the VOC concentration and LEL in the exit pipe that connects the sealing liquid separator tank [13.002] to the flare.

16. Measure the vacuum in each well by observing the gauge at each well head.

17. Raise the draw-down tube in those wells that did not have any floating fuel product in them at the start, and close the valve at those wells.

18. Lower the draw-down tube in "product wells" to the proper depth. First the wellhead seal assembly should be loosened just enough to allow movement of the draw-down tube down the well casing. As the tube is lowered, the operator should watch the sight glass and note when there is liquid flowing. From previous measurements, the thickness of product in each well should be known (Step #3). The operator will then carefully lower the tube the distance of the measured product thickness in that specific well. Observing any additional liquid or a different type of liquid in the sight glass indicates that groundwater is being extracted from the well. If this is the case, the draw-down tube should be raised slightly. After tightening the wellhead cast iron well seal assembly, the operator should take a sample of the liquid extracted from the well by closing the well header valve and opening the sample valve. After closing the sample valve, the well header valve should be opened again.

19. Check the depth to water, depth to product, and product thickness in all wells weekly, or more frequently on an as-needed basis. The depth of the draw-down tube should be adjusted in accordance with these weekly measurements.

20. Measure the VOC concentration and LEL in the exit pipe from the sealing liquid separator tank [13.002]. After all the draw-down tubes have been located at their proper depth, the VOC concentration and LEL should be measured when vacuum pumping begins and after four hours of operation. If necessary, depending on operating experience, the measurements should continue every four hours. Following several days of these four-hour measurements, the measurement should be conducted daily. After the first week of operation the measurements should be conducted weekly. Each time the VOC concentration and LEL are measured, the oxygen concentration is also to be measured in the exit pipe. A sampling port is located outside the enclosure on the exit air pipe.

21. Observe the flare tip and make sure that it is operating in a smokeless manner. Generally, there is insufficient oxygen in the mixture going to the flare if it is generating smoke. The operator should open the vent valve on the knock-out tank to increase the oxygen content of the exit air. The vent valve should be adjusted so there is no smoke being generated while also ensuring there is a minimum volume of air being added to the knock-out tank. If the flare cannot operate in a smokeless manner by adjusting the ambient airflow, propane spike gas must be added to the system. The gate valve on the propane line entering the exit air pipe should be opened. This allows propane to enter the air stream at the flare tip.

22. The bluebox heat thermostat controls the interior air at 50 degrees Fahrenheit. The thermostat controlling the seal water should be set at 80 degrees Fahrenheit.

23. Measure the thickness of product in the oil/water separator [09.001] on a weekly basis and determine the volume of product stored in the oil waste drum on a weekly basis.

3.2 START-UP FOLLOWING SHORT DOWNTIMES

Following is an outline of procedures necessary for start-up after short downtimes. Actual step-by-step procedures will depend on the reason for shutdown. The procedures for initial start-up, although more lengthy and complete, can always be followed for any start-up. The operator should perform the following activities:

- Notify the base environmental department that a start-up is planned.

- Make sure the inlet valves to the knock-out tank [13.001] and exit valves to the flare system are open.

- Make sure the oil/water separator [09.001] is filled with water to the proper operating level.

- Make sure that the make-up water tank [09.002] is full, and connected to the base water supply.

- Start the flare pilot.

- Start the vacuum pump [02.001].
- Check the system for leaks.
- Monitor and adjust the depth of the draw-down tubes.
- Monitor the VOC concentration, oxygen, and LEL in the exit air going to the flare.
- Monitor the operation of the flare and, if necessary, add spike gas to ensure a smokeless operation.

4.0 OPERATOR'S DUTIES AND PROCEDURES

The operator's duties include start-up, routine shutdowns, and the day-to-day operations and monitoring requirements. The operator's attention to detail and monitoring actions conducted on a routine and consistent schedule will produce the optimum treatment results.

Operations should be documented and maintained for information, future referral, and reporting purposes. Operating records should be prepared for routine duties, used as a reference for system operations, and reported as required.

The following is a summary of the operator's duties.

4.1 ROUTINE SYSTEM SHUTDOWN

1. Notify the base Civil Engineering Environmental department when the system is shut down. This should be done in advance of a scheduled shutdown, or as soon as practical following an unscheduled shutdown. The environmental department should be told the time of shutdown and the estimated length of time the system will be down.

2. Open the vent valve on the knock-out tank [13.001] to its full open position first. Then, the inlet valves to the knock-out tank should be closed.

3. Operate the system in this mode until all the pressure lines have been purged with clean air.

4. Shut off the vacuum pump [02.001].

5. Continue operating the flare unit unless the shutdown is to work on the flare. When working on the flare, the propane to the flare pilot must be shut off. Push the spike gas shutoff on the flare (red button) used to shut off the propane supply.

4.2 MALFUNCTION SHUTDOWN

1. Notify the base environmental department.

2. Determine the most logical reason for system shutdown.

3. Repair as required.

4. Follow steps 2 through 5 in Section 4.1 for routine shutdown.

4.3 EQUIPMENT MONITORING

1. Monitor the vacuum wells as specified below.

   a. Daily: View sight glass for liquid flow indication.

   b. Daily: Measure pump vacuum.

   c. Daily: Ensure there are minimum leaks at the wellhead.

d. Daily: Open the sample valve and collect any liquid that may have accumulated in the sample line. Observe the types and relative percentage of liquids collected (i.e., water or floating products).

e. Weekly: Measure the depth to water and depth to product as well as product thickness. Record the information at end of week.

f. Monthly: At nonproduct wells measure pump vacuum from the radius of influence from other product wells.

2. Header Pipeline Monitoring

a. Daily: Ensure the individual valves are in the proper open or closed position.

b. Weekly: Make sure there are minimum leaks in the header pipelines.

c. Weekly: During winter months, check the thermostats on the heat-tracing circuits to ensure the set points are 50 degrees Fahrenheit, and that the switches are operating. Also, turn the shaft from the motor to the vacuum pump [02.001] one complete rotation.

3. Vacuum Pump Area Monitoring [02.001]

a. Daily: Measure vacuum on inlet pipe to the vacuum pump.

b. Daily: Measure for VOCs, oxygen, carbon dioxide, and LEL in the exit air.

c. Daily: Fill make-up water tank [09.002].

d. Daily: Check for liquid and air leaks.

e. Daily: Check the air/heat exchanger [11.001] thermostat and the bluebox interior air thermostat.

f. Daily: Observe the operation of the oil/water drain pump [01.001] on the outlet side of the knock-out tank [13.001].

g. Daily: Observe the operation of the seal water circulating pump [01.002] and air/water heat exchanger [11.001] shutters.

4. Oil/Water Separator Monitoring [09.001]

a. Daily: Check to make sure that water and product are being discharged properly.

b. Daily: Make sure that there are no leaks from the vessel or piping.

c. Weekly: Measure product thickness in the separator.

d. Weekly: Determine the volume of product in the waste oil accumulation drum.

e. Weekly: Collect a water discharge sample at the separator drain pump [01.003] for biochemical oxygen demand (BOD) and oil/grease analyses.

5. Flare

a. Daily: Check for smokeless operation.

b. Daily: Check the propane level in the propane supply tank. Order more propane when the tank is less than 50 percent full.

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5.0 MAINTENANCE

5.1 GENERAL MAINTENANCE

Efficiently operating the vacuum system and recovering the maximum petroleum product requires periodic maintenance to ensure optimum operation, and minimal downtime and repairs. The following is a suggested maintenance program schedule.

5.2 HEAT TRACING

Annually: Before subfreezing weather, check all heat-tracing circuits for proper operation and set thermostats to energize at 50 degrees Fahrenheit.

5.3 PIPELINES

Monthly: Conduct an inspection of all pipelines and check for leaks, damaged insulation, etc. Repair damages as quickly as possible.

5.4 VACUUM PUMP [02.001]

50 Hours: After the first 50 hours of operation clean all filters or strainers in the system to remove any foreign material.

1,000 Hours: Clean filters and strainers.

3,000 Hours: Grease the bearings on the vacuum pump. A moisture resistant number 2 lithium based grease should be used. Check the condition of the drive coupling.

Note: Cavitation is recognized by a characteristic metallic or grinding noise inside the pump. It is caused when the pump suction pressure is too close to the vapor pressure of the seal water. When cavitation occurs, vapor bubbles form and collapse within the liquid ring. This erodes the surfaces of the impeller, side plate, and casing. Cavitation is prevented by bleeding air into the pump casing.

See pages 22 and 23 of the INTERVAC operation and maintenance manual in Appendix C for a trouble-shooting reference chart.

5.5 OIL/WATER SEPARATOR [09.001]

Semiannually: Check to make sure that the level of sand, dirt, or debris is less than 6 inches from the bottom of the separator. Remove the accumulated material with a suction hose or portable sludge pump.

Monthly: Check to make sure that the level of oil and grease is not less than half the height of the separator (50 percent of separator volume). Remove the accumulated oil with a suction hose or a portable oil pump.

See the manufacturer's operation and maintenance instructions contained in Appendix C for more details.

5.6 FLARE

See the manufacturer's operation and maintenance instructions contained in Appendix C for details on the flare system.

5.7 WINTERIZATION

The goal of winterization is to protect the liquid ring seal vacuum pump [02.001] and other mechanical system devices from freeze damage. The system internal heater will remain **ON** during the entire winter period. Normal base health and safety procedures associated with operation of mechanical or flammable equipment should be followed at all times when maintaining/operating this equipment. The Eielson AFB free product removal system winterization procedures are presented in the following sections:

5.7.1 Drain Residual Header System Liquid

The following steps are to be followed to purge the header pipes of residual liquid:

- Disconnect flexible pipe from the well field 1 wellhead assemblies (these are the four extraction wells next to the power plant).

- Configure header system valves to draw fresh air from well field 1 while blowing into well field 2 (well field 2 consists of the five extraction wells directly south of the bluebox). Run the system 5 minutes.

- Reconnect the flexible pipe to the well field 1 wellhead assemblies.

- Disconnect the flexible pipe from the well field 2 wellhead assemblies.

- Configure the header system valves to draw fresh air from well field 2 while blowing into well field 1. Run the system 5 minutes.

- Reconnect the flexible pipe to the well field 2 wellhead assemblies.

- Open the wellhead assembly sample ports and drain any accumulated water. Close the wellhead assembly sample ports.

5.7.2 Clean Out System (Phase 1)

The following procedures must be followed to prepare the bluebox system for winterization:

- Drain/drum water from the knock-out tank [13.001], sealing liquid separator tank [13.002], and the oil/water separator [09.001]. Drainage valves for each of these pieces of equipment are located on the exterior of the bluebox enclosure. Leave the power on while draining the separator tank to allow the make-up water tank [09.002] to drain. Close valves when complete and replace the threaded plugs.

- Unbolt the top of the oil/water separator [09.001] and inspect for sludge. Clean out and drum all observed sludge. Close the oil/water separator.

5.7.3 Winterize Vacuum Pump (Liquid Ring Seal Pump) [02.001]

The following steps describe the winterization of the vacuum pump. It is important that the vacuum pump be filled with a solution of water and antifreeze (usually ethylene glycol) to ensure that the pump is not damaged if the interior of the bluebox falls below 32°F. Water freezing in the vacuum pump may severely damage the pump.

- Open the filter screen port in the seal water circulation system and clean the filter screen. Replace the screen and close the port.

- Charge the sealing water separator tank [13.002] with commercially available antifreeze (with rust inhibitors) diluted as appropriate for the Fairbanks area weather conditions. Fill the separator tank to one-half the level glass. Please note that antifreeze is toxic when ingested, and spills must be cleaned up immediately in accordance with base standard procedures.

- Close all wellhead assembly valves to prevent flow into the extraction wells.

- Open the appropriate valves on the header piping in order to recirculate system air through the vacuum pump. Run the system for 10 minutes. The antifreeze concentration in the separator tank will decrease as the mixture is diluted with seal water entrained in the air/water heat exchanger [11.001] and vacuum pump.

- Test the antifreeze concentration in the separator tank. Add additional antifreeze, as necessary, and run the system for 10 minutes. Repeat this step until the antifreeze concentration protects the equipment to a minimum of -45°F.

5.7.4 Clean Out System (Phase 2)

The pumps connecting the knock-out tank [13.001] and the oil/water separator [09.001], and the separator drain pump [01.003] should be drained of all fluid.

- Disconnect the oil/water drain pump [01.001] that connects the knock-out tank [13.001] and oil/water separator [09.001]. Drain/drum all pump water and then reconnect.

- Disconnect the separator drain pump [01.003]. Drain/drum all pump water and then reconnect.

5.7.5 Shut Down Flare

- Close all propane valves.

- Turn off all flare systems.

- Turn off the power switch below the flare control panel.

- Turn off the main power to the flare at the main service control panel (located approximately 50 feet northeast of bluebox).

- If power to igniter cannot be maintained during shutdown period, restart of system may require drying out igniter (see Startup).

5.7.6 Shut Down Vacuum Extraction Unit

- Close all wellhead assembly valves (including sample ports).

- Open all header system valves except for the valve leading to the flare.

- Seal louvers with tape to prevent ambient air infiltration.

- Close all doors.

- Leave the system power <u>ON</u> to allow heater operation.

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6.0 HEALTH AND SAFETY

When operating the Treatability Study system, it is vital to remember that the vapor being pulled from the vacuum wells and exiting the vacuum pump may exceed the LEL for a petroleum and air mixture. The second most important factor to remember is that the operation of the Treatability Study system is not an industrial process where it must operate 24 hours every day. If there is any concern about safe operation, the system should be shut down until that concern is resolved.

No smoking is allowed within 25 feet of the operating system, including the well heads. No welding or torch cutting is allowed on any of the system piping or vessels unless the system has been purged with ambient air (wellhead valves fully closed) and tested. In addition, the VOC and oxygen concentrations, and percent LEL must have been measured in the immediate work area and within the entire enclosure area. The percent LEL and VOC concentration measurements in the entire bluebox enclosure area must be zero before any maintenance work can begin.

Generally, the bluebox enclosure panels near the equipment to be worked on should be removed to allow easy access and adequate ventilation.

All polyvinyl chloride (PVC) or carbon steel pipelines should only be worked on after they have been purged (wellhead valves fully closed) with ambient air, and the percent LEL of the purged air exiting the pipelines has been checked. Work can only begin if the percent LEL is zero and the wellhead valves have been fully closed.

The vacuum pump [02.001] is driven by a 75 horsepower motor. There are three small pumps and motors (seal water circulating pump [01.002], oil/water drain pump [01.001], and separator drain pump [01.003]) within the enclosure. These pumps require an enclosure over the couplings before full-time operation of the unit is permitted. The operator should stay away from these pump and motor assemblies when the system is operating. When maintenance is required on any motor or pump, the operator must shut down the system at the power control panel and follow standard lock-out procedures (i.e., locking and tagging the control panel so that only the operator can turn on the power after the maintenance work has been completed).

The bluebox enclosure heater [11.001] is electric and will be hot when it is operating. The operator should stay away from the heater when it is operating. If the heater requires maintenance, the operator should turn the power off to the entire system and lock-out the control panel. Maintenance work can only begin after the heater has cooled to ambient temperature and the system has been purged (wellhead valves fully closed) with ambient air.

When the flare is operating, no one (including the operator) shall stand within 15 feet of the flare pipe stack.

The operator shall wear sturdy boots, safety glasses with side shields, and a hard hat at all times when he or she is operating or maintaining the system. The operator shall also have a respirator readily available in case it is needed during an emergency. Maintenance personnel shall wear sturdy boots, safety glasses with side shields, and a hard hat.

7.0 MOVING THE SYSTEM

This section presents general procedures on the disassembly, transport, and reassembly of the Site 48 Treatability Study equipment (flare, bluebox, and ancillary equipment). This section is intended as a general guide and qualified construction personnel should supervise the activities associated with moving the system. If the system is to be moved to a new site, a complete engineering and hydrogeologic design must be completed for the new site including design of extraction wells, header piping, valve placement, and full integration of the bluebox enclosure into the new system. (Note: The amount of spike gas supplied within the flare must be reevaluated. Any modifications to the flare should be performed prior to erection of flare at the new location.) Obviously, some of the equipment currently onsite may be moved along with the bluebox and the flare. However, much of the system will have to constructed and/or fabricated at the new operation site.

7.1 BREAKDOWN OF EQUIPMENT

If the system is to be moved from Site 48 to a new site, all equipment and piping must be broken down and disassembled. The basic steps for breakdown are summarized as follows.

- The entire system must be purged with ambient air to remove all VOC vapors in the piping (both header piping and piping within the bluebox enclosure).

- The insulation on all piping should be removed, and heat tracing turned off at the main power panel and removed from all piping. Every effort should be made to preserve the insulation and heat tracing for possible reuse at the new site or another location.

- Once the insulation and heat tracing have been removed from the piping, the piping must be taken apart at the flanged locations at each butterfly valve and other locations deemed necessary by site personnel for safe movement of the pipe. The flame arrestor on the exit air line from the bluebox to the flare should be unbolted at the flanged connections and stored before transport.

- All piping should be steam-cleaned before disposal or reuse. The rinsate liquid should be contained and disposed of in accordance with all appropriate base procedures.

- All liquid should be drained from the equipment in the bluebox. This includes all liquid transfer pumps [01.001, 01.002, and 01.003], the knock-out [13.001], separator tanks [13.002], oil/water separator overflow tank [09.003], piping for the air/water heat exchanger [11.001], make-up water tank [09.002], vacuum pump [02.001], and the oil/water separator [09.001]. This liquid should be contained and disposed of in accordance with all appropriate base procedures. All equipment must be flushed clean to remove all combustible residues.

- If the equipment at each well head (including the drawdown tubes) is to be reused, the equipment must be broken down and cleaned of all residual contamination. The well head at each well must be sealed or retrofitted with new equipment if the wells are to be used for a different purpose (e.g., bioventing, etc.).

7.2 REMOVAL OF BLUEBOX SYSTEM

Once all inlet and outlet piping has been disconnected from the bluebox and all residual liquid drained from the system inside the enclosure, power must be turned off at the system main service panel located approximately 50 feet northeast of the bluebox enclosure. Currently the power line is run underground to the bluebox. This power line must be disconnected at the bluebox and removed from the enclosure to the main panel. All electrical work must be supervised by a qualified electrician or qualified personnel from the base Civil Engineering Electrical department.

Once the power has been shut off and removed, the bluebox is ready to be moved. A lifting device with adequate capacity must be used to move the bluebox. The bluebox was loaded by the vendor using two 8,000-pound capacity forklifts. No weight was provided by the vendor, but the estimated weight is approximately 14,000 pounds. The bluebox is sized to be moved by aircraft or truck. A multipoint pick is required to prevent damage to the bluebox framing or equipment while setting it on a truck to be transported to another site. The lift of the bluebox must be supervised by experienced riggers to ensure that the bluebox is not damaged during movement.

7.3 MOVEMENT OF THE FLARE SYSTEM

Once all piping from the bluebox enclosure to the flare (the exit air line) has been removed, the electrical power must be shut off at the main service control panel approximately 50 feet northeast of the bluebox. The electrical line to the flare currently runs underground from the service panel to the flare. This line must be disconnected at the flare control panel and removed. All electrical work must be supervised by a qualified electrician or qualified personnel from the base civil engineering electrical department.

The propane supply line to the flare must be shut off and disconnected at the propane tank and at the flare (a union is located on the flare side to disconnect this line). Once this has been accomplished, the flare stack is ready to be lifted and removed. There are lifting eyes on the flare approximately 30 feet up the stack. A crane must be used to hold the flare at the lifting eyes while the guy anchor cables are loosened. After the guy cables are loosened and slack, the stack should be unbolted at the base of the flare and the guy lines disconnected. The flare can then be picked up and set on a truck for transport. If the flare barrel is too long for transportation, the middle flanged connections can be unbolted to provide shorter pieces. However, reassembly will require new gaskets and possibly new wire for the external electrical circuitry.

Since the control panel and ignitor assembly for the flare will still be connected, special care should be taken not to damage these components. The flare is designed to be moved with these components in place.

The guy lines should be moved with the flare. The concrete base pad and guy anchor pads can either be left in place or removed and disposed of. New concrete pads will have to be constructed at the new site to anchor the flare.

It should be noted that most of the piping, heat tracing, insulation, and wellhead equipment can be reused at the new site. If this is the case, arrangements must be made to transport all of this equipment with the flare and bluebox.

7.4 ASSEMBLY OF EQUIPMENT AT NEW SITE

As stated previously, a new design for the site that will receive the equipment must be done in advance. This includes installing new wells or retrofitting old wells for extraction purposes, new piping design, new electrical design for service to the system and the possible installation of water service to be used for seal water in the vacuum pumps. The existing equipment must be fully integrated into the new design to ensure the system will operate successfully.

The following issues must be addressed when the system is set up at a new site.

- See Section 7.2 for lifting precautions. A compacted crushed gravel base pad (minimum 12-inch thickness) must be placed for the bluebox to be set on.

- New concrete pads must be constructed for the flare base and guy anchors. These must be designed for the new site conditions (soil, weather, and other parameters).

- A source of propane for the flare pilot and spike gas must be located at the site.

- The coupling between the vacuum pump and its motor must be checked for proper alignment, and realigned if necessary.

- Follow all startup procedures in Section 3.0 of this manual and the manufacturer's procedures located in Appendix C.

- A source of process water (20 psi minimum pressure) should be run to the site to be used as seal water for the vacuum pump.

All assembly, start up, and operation activities should be performed by personnel experienced with this system. All electrical work should be performed by qualified electricians or qualified base personnel. All crane operations should be supervised by a licensed operator. A new Health & Safety Plan should be developed for the new site and should include construction and operation issues.

SITE 48 TREATABILITY STUDY
EIELSON AIR FORCE BASE
START-UP CHECKLIST

BEFORE STARTUP

- Notify power plant personnel.
- Notify Eielson AFB environmental staff.
- Check for proper operation and calibrate all field instruments.

SYSTEM CHECKOUTS BEFORE STARTUP

- Visually check header and extraction well piping for leaks and other problems.
- Visually check positions of header piping valves to make sure that they are in the correct position for operation. The valves may be configured to route exit air to the flare, or exit air may be reinjected into either well field.
- Check status of electrical power to the main service panel of the bluebox and to the flare.
- Check each extraction wellhead assembly (i.e., well seals in good operation and line valves in good operating mode).
- Check the propane supply by the gauge on top of tank. If the tank is less than 50 percent full, the operator must order more propane.
- Check the water level in the oil/water separator. The separator must be nearly full for efficient operation.
- Check the flare system operation in accordance with the manufacturer's recommendations in Appendix C of this Operations and Maintenance Manual.
- Open the doors of the bluebox enclosure to allow good ventilation and observation of vacuum pump and ancillary equipment.

SYSTEM START-UP

- Measure depth to product and depth to water in each of the extraction wells.
- Raise draw-down tube to the top of the casing in each extraction well.
- Check the amount of product in the storage drum. If the drum is 80 percent full, replace it with a new one.
- Open the line valves at each extraction well head and the inlet valve to the knock-out tank.

- Open the valve to the flare on the exit pipe from the sealing liquid separator tank (making sure the valves on the injection pipelines are closed).

- Start the flare pilot.

- Energize the bluebox system.

- Operate the system for approximately one day with the draw-down tubes in the raised position.

- Observe the flare to ensure that the off-gas is being burned in a smokeless manner.

- For those extraction wells where there is floating product in the casing, gradually lower their respective draw-down tubes to the top of the water column in the casing.

- Observe the liquid flow from the well and note the depth of the draw-down tube (thus, the height of the water column).

- Raise the draw-down tube slightly above the top of the water column. If the difference between the static (nonvacuum) water column depth and the vacuum water column depth is greater than 1 foot, then raise the draw-down tube to the bottom of the well seal.

- After the draw-down tubes are in their proper position, measure the vacuum at each well head.

- Measure the percent lower explosive limit (LEL), volatile organic compound (VOC) concentration, and oxygen concentration in the exit vapor from the separator tank.

- Check for VOC leaks in the piping with proper instrumentation.

- Check for VOC leaks around the vacuum pump and ancillary equipment (e.g., tanks, liquid pumps, heat exchanger, etc.).

- Observe the flare operation to ensure that there is a flame for thermal destruction of the VOCs and the operation is smokeless.

- After the system is operated for a period of time, the VOC concentration in the exit air may decrease to the point that the flare is not operating in a smokeless manner. If this is the case, open the spike gas valve on the propane line leading into the exit air pipe or reconfigure the header piping valves to reinject air into either well field for bioventing purposes.

SITE 48 TREATABILITY STUDY
EIELSON AIR FORCE BASE, ALASKA
EXTRACTION WELL GAUGING LOG SHEET

OPERATOR NAME: ______________________

DATE:

WELL ID.	DEPTH TO WATER (FEET)	DEPTH TO PRODUCT (FEET)	PRODUCT THICKNESS (FEET)	REMARKS
VEW-01				
VEW-02				
VEW-03				
VEW-04				
VEW-05				
VEW-06				
VEW-07				
VEW-08				
VEW-09				

APPENDIX C

TABLE OF CONTENTS

EQUIPMENT LIST

Equipment Number	Description
Equipment Inside Blue Box	
11.002	Air Heater Electric
01.001	Oil/Water Drain Pump
13.001	Knock-Out Tank
02.001	Vacuum Pump
13.002	Sealing Liquid Separator Tank
22.001	Strainer
01.002	Seal Water Circulating Pump
09.002	Make-up Water Tank
01.003	Separator Drain Pump
09.003	Oil/Water Separator Overflow Tank
09.001	Oil/Water Separator
11.001	Air/Water Heat Exchanger
Equipment Outside Blue Box	
36.001	Flame Arrestor
36.002	Flare Tip

Equipment numbers are same as those shown on P&ID drawing EIE-100-002.

100% Recycled

BILL OF MATERIALS

INTERVAC LIQUID RING VACUUM PUMP PACKAGE

MODEL: PSW1000/1-1FR
SERIAL: 92052544

Furnished by:

Intervac Corporation
125 Rawson Road
Victor, NY 14564
(800) 433-8487
(716) 924-7080

	EQPT #
INCLUDES:	
- Pump Model: PLM73/5C-F	[02.001]
- Motor: 75 HP, 1,200 RPM XPCL1GP C&D	
- Heat Exchanger: 3 HP x PGL 1 GP D	[11.001]
- Circulation Pump: 1/2 HP, 3,600 RPM x PCL1GPD	[01.002]
- Separator Tank	[13.002]
- Temperature Gauge	
- Y Strainer - 2"	[22.001]
- Regulating Valve 2" Globe	
OIL WATER SEPARATOR	[09.001]
Model: HTL-30	
Furnished by: Highland Tank Company, Stoytown, PA 15563, (814) 893-5701	

EQPT #

KNOCKOUT TANK

Model: 35596 [13.001]

- 240 gallon vertical
- Tank modified by air components

Furnished by: Manchester Tank & Equipment Company

OIL WATER SEPARATOR OVERFLOW TANK 15 GALLONS [09.003]

Model: 61-0151

Furnished by: Manchester Tank & Equipment Company

MAKEUP WATER TANK FOR SEALING WATER

Model: 61-0301 [09.002]

- 30 gallons

Furnished by: Manchester Tank & Equipment Company

FLAME ARRESTER WITH 3/4" OPTIONAL FITTING FOR TEMPERATURE PROBE [36.001]

Model: C25006/0041

Furnished by: Protectoseal Company
225 Foster Avenue
Bensenville, IL 60106
(708) 595-0800

ALL FLOAT SWITCH

Model: L-1200HP

Furnished by: Frank W. Murphy Company
Tulsa, OK 74147
(918) 627-3550

SOLENOIDS

Model: 44629F

Manufactured by: Asco

EXPLOSION PROOF HEATER

Model: HLA16-480360-10-24 [11.002]

- 10 KW, 34120 BTU, 480 VAC, 3 PH

Furnished by: Markel Products
Johnson City, TN 37601
(615) 282-4131

EQPT #

HEATER THERMOSTAT

Model: TW161

Furnished by: Markel Products
Johnson City, TN 37601
(615) 282-4131

SHUTTERS

Model: 3C132

Furnished by: W.W. Grainger Company

SHUTTER MOTOR

Model: 2C832B

Furnished by: W.W. Grainger Company

PRESSURE SWITCH

Model: SA20D-TD2A21

- Set for 5 PSIG

Furnished by: W.W. Grainger Company

TEMPERATURE GAUGES

Model: Ashcroft 2A613

Furnished by: W. W. Grainger Company

SHUTTER CONTROL THERMOSTAT & CABINET CONTROL TEMPERATURE THERMOSTAT

Model: 2E449

Furnished by: W.W. Grainger Company

SPARATOR DRAIN PUMP FLUID PACK

Model: 1312 1/2 x 1 x 6 [01.003]

- Explosion proof 3/4 HP, 460 V, 3 PH

OIL-WATER DRAIN PUMP

Model: 1312 2 x 1 1/2 x 6 [01.001]

- Explosion proof 1/2 HP, 1750, 3 PH, 460V

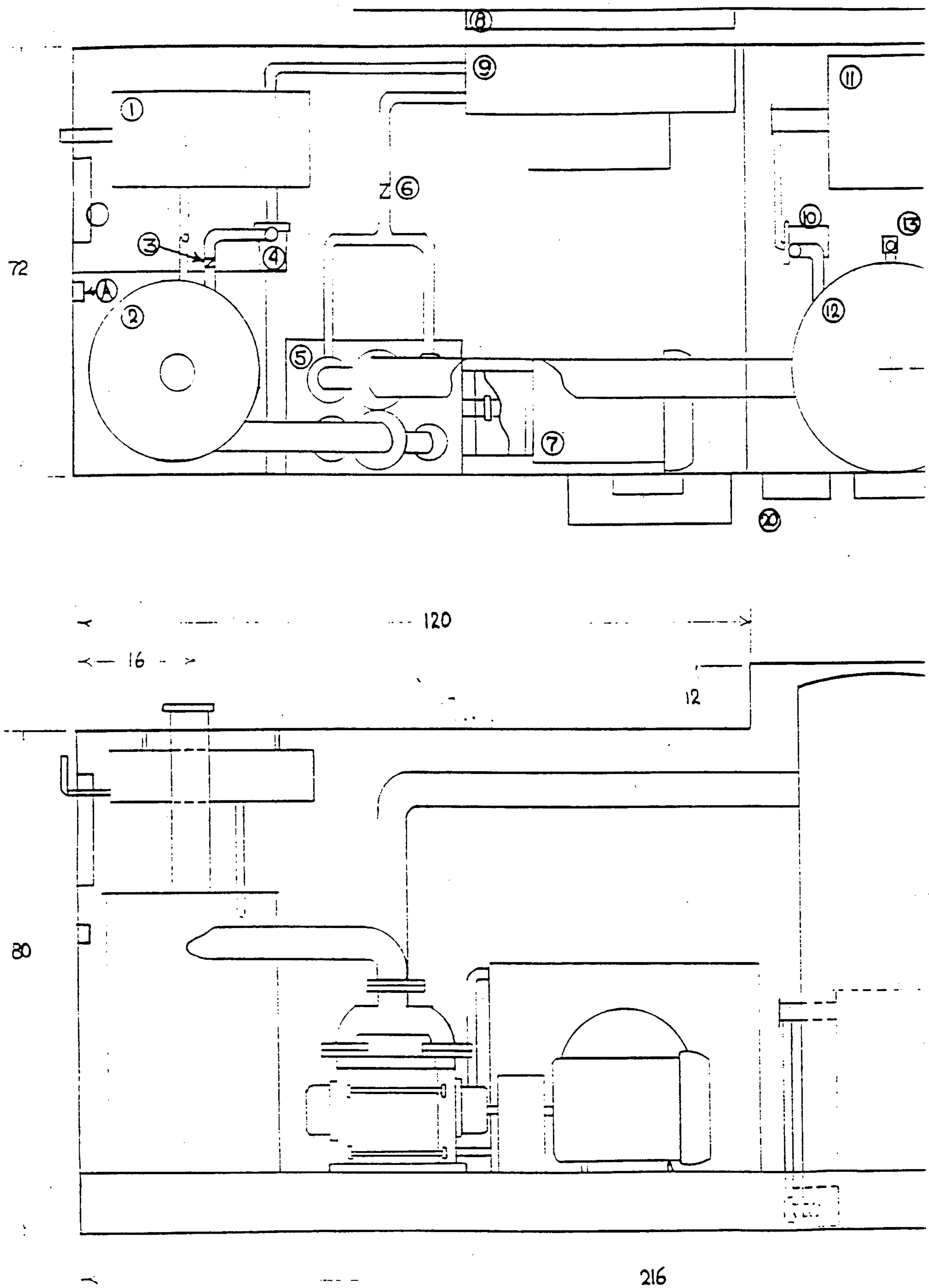
EQPT #

CABINET

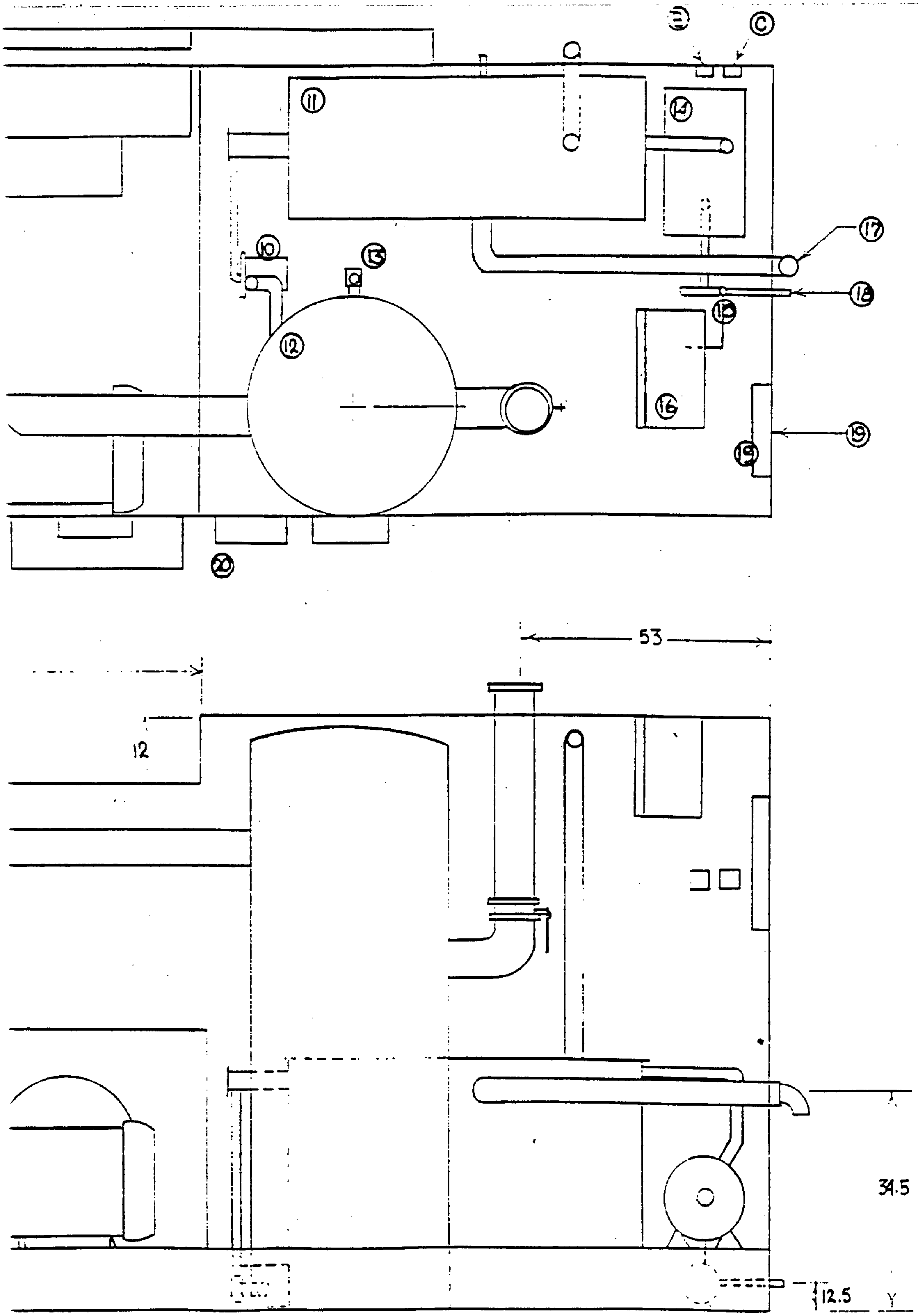
Manufactured by: Air Components

Recommended Spare Parts List

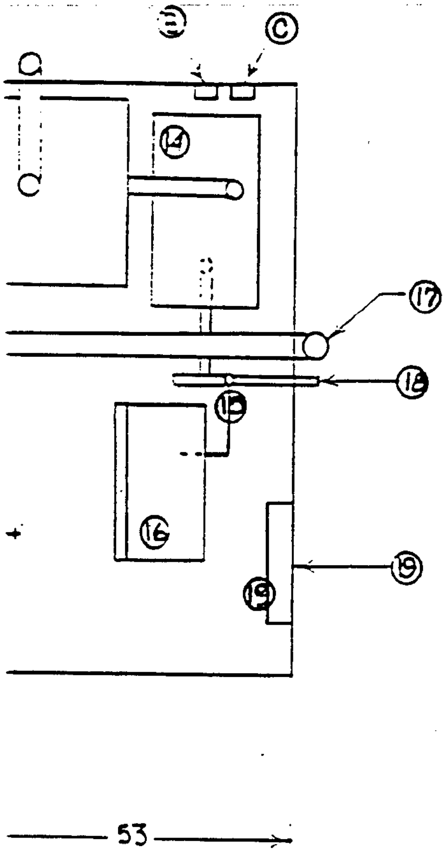
INTERVAC MOTOR TO PUMP COUPLING MOTOR	
Model: 21266-2188	$153.31
- 2 7/8 hub	
Furnished by: P.N. Woods	
PUMP	
Model: 21266-060	$392.39
- 60 mm	
Furnished by: P.N. Woods	
ELEMENT	
Model: 22210-012	$235.71
Furnished by P.N. Woods	
PUMP REPAIR KIT	
Model: P1M7315C-F	$500.50
TWO MECHANICAL SEALS	
Model: 950 075 SAC 915	$500.50
BALL BEARING	
Model: 961 006 314 000	$330.16

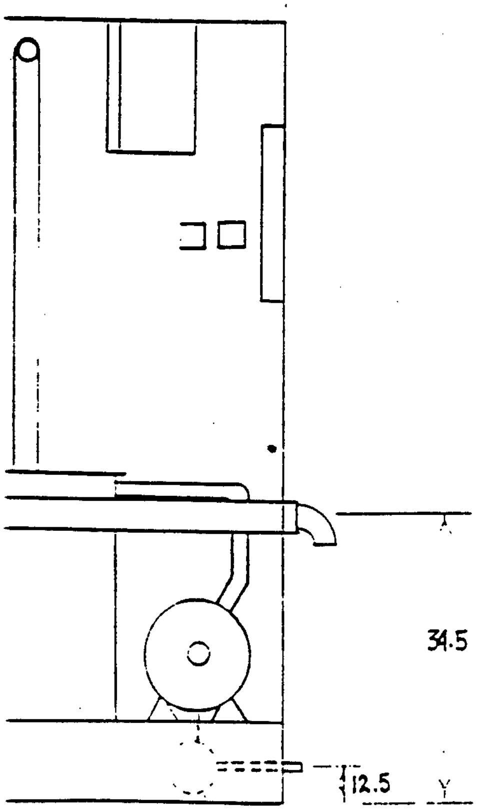


1

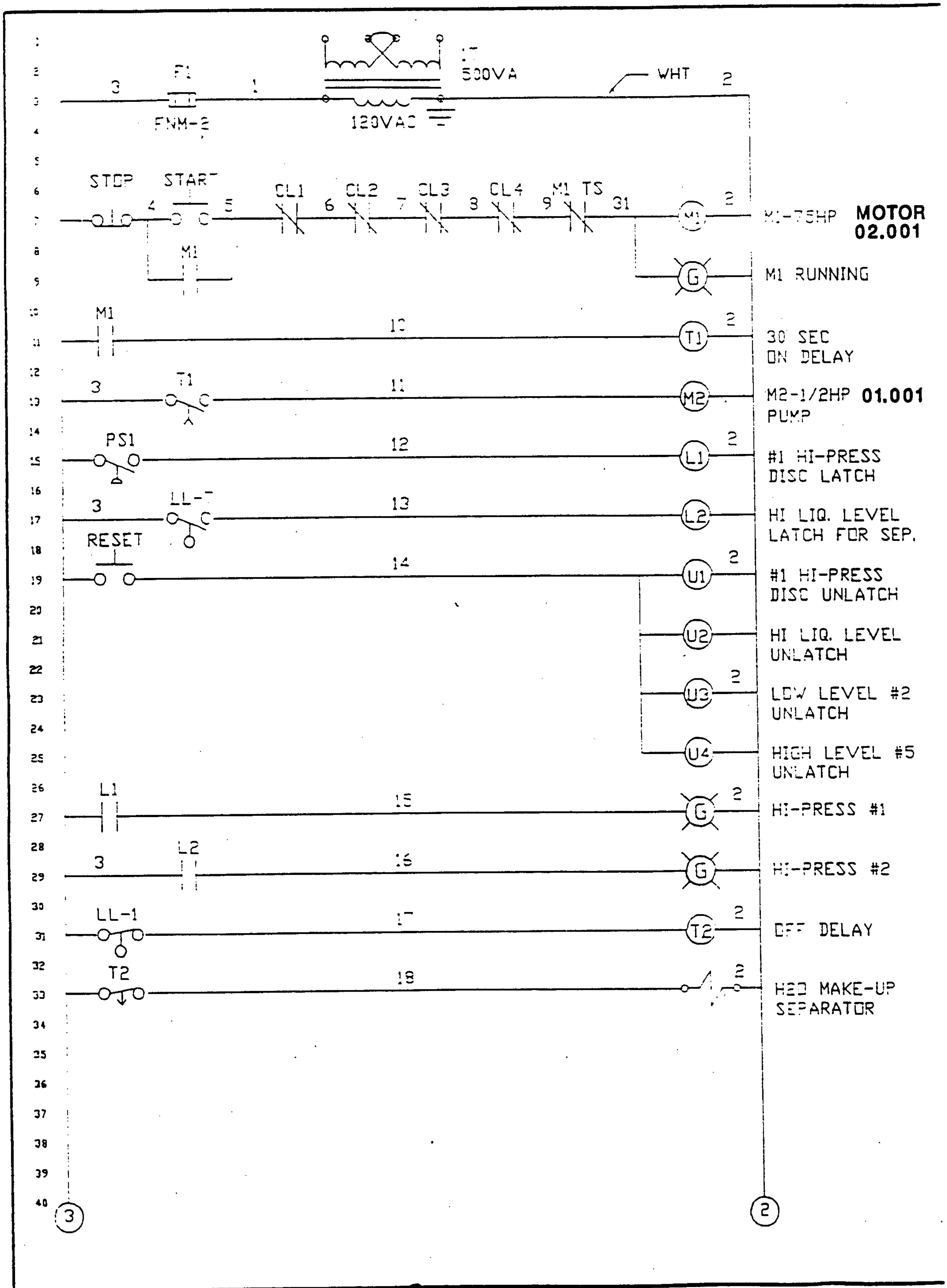


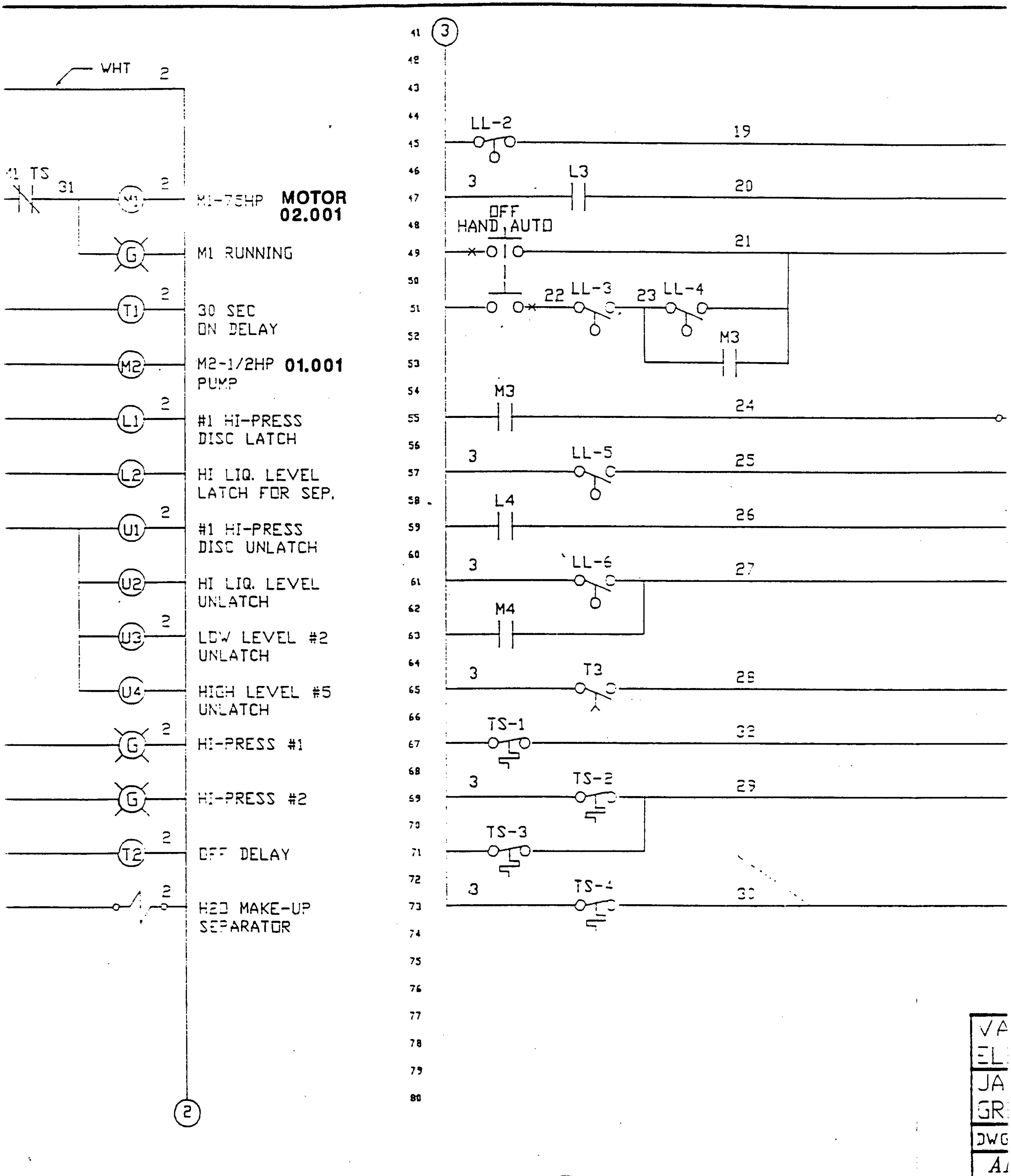
	ITEM
1	MAKE UP WATER T/
2	SEALING LIQUID SP.
3	STRAINER
4	SEAL WATER CIRCU
5	500 CFM VACUM PUI
6	TEMPERATURE SWI
7	75 HP MOTOR
8	SHUTTER
9	AIR/WATER HEAT E
10	OIL/WATER DRAIN I
11	OIL/WATER SEPERA
12	KNOCK OUT TANK V
13	VACUM UNLOADIN(
14	OIL/WATER SEPERA
15	SEPERATOR DRAIN
16	AIR HEATER ELECT
17	OUTLET FOR OIL 3"
18	OUTLET FOR WATEI
19	LOUVER
20	ELECTRICAL PANEL
A	HEATER THERMOST
B	LOUVER THERMOST
C	FAN THERMOSTAT





	ITEM	EQPT#
1	MAKE UP WATER TANK	09.002
2	SEALING LIQUID SPERATOR TANK	13.002
3	STRAINER	22.001
4	SEAL WATER CIRCULATING PUMP	01.002
5	500 CFM VACUM PUMP	02.001
6	TEMPERATURE SWITCH	
7	75 HP MOTOR	
8	SHUTTER	
9	AIR/WATER HEAT EXCHANGER	11.001
10	OIL/WATER DRAIN PUMP	01.001
11	OIL/WATER SEPERATOR	09.001
12	KNOCK OUT TANK W/6"INLET	13.001
13	VACUM UNLOADING SOLINOID	
14	OIL/WATER SEPERATOR OVER FLOW TANK	09.003
15	SEPERATOR DRAIN PUMP	01.003
16	AIR HEATER ELECTRIC (5KW)	11.002
17	OUTLET FOR OIL 3" TO 1"	
18	OUTLET FOR WATER	
19	LOUVER	
20	ELECTRICAL PANELS	
A	HEATER THERMOSTAT	
B	LOUVER THERMOSTAT	
C	FAN THERMOSTAT	


F1
FNM-2
500VA
120VAC
WHT
STOP
START
CL1
CL2
CL3
CL4
M1
TS
M1-75HP
MOTOR 02.001
M1 RUNNING
30 SEC ON DELAY
T1
M2-1/2HP 01.001 PUMP
PS1
#1 HI-PRESS DISC LATCH
HI LIQ. LEVEL LATCH FOR SEP.
RESET
#1 HI-PRESS DISC UNLATCH
HI LIQ. LEVEL UNLATCH
LOW LEVEL #2 UNLATCH
HIGH LEVEL #5 UNLATCH
L1
HI-PRESS #1
L2
HI-PRESS #2
LL-1
OFF DELAY
T2
H2O MAKE-UP SEPARATOR


WHT
2
TS
31
M1
M1-75HP MOTOR
02.001
M1 RUNNING
30 SEC
ON DELAY
M2-1/2HP 01.001
PUMP
#1 HI-PRESS
DISC LATCH
HI LIQ. LEVEL
LATCH FOR SEP.
#1 HI-PRESS
DISC UNLATCH
HI LIQ. LEVEL
UNLATCH
LOW LEVEL #2
UNLATCH
HIGH LEVEL #5
UNLATCH
HI-PRESS #1
HI-PRESS #2
OFF DELAY
H2O MAKE-UP
SEPARATOR
LL-2
19
L3
20
OFF
HAND AUTO
21
22
LL-3
23
LL-4
M3
24
LL-5
25
L4
26
LL-6
27
M4
T3
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TS-1
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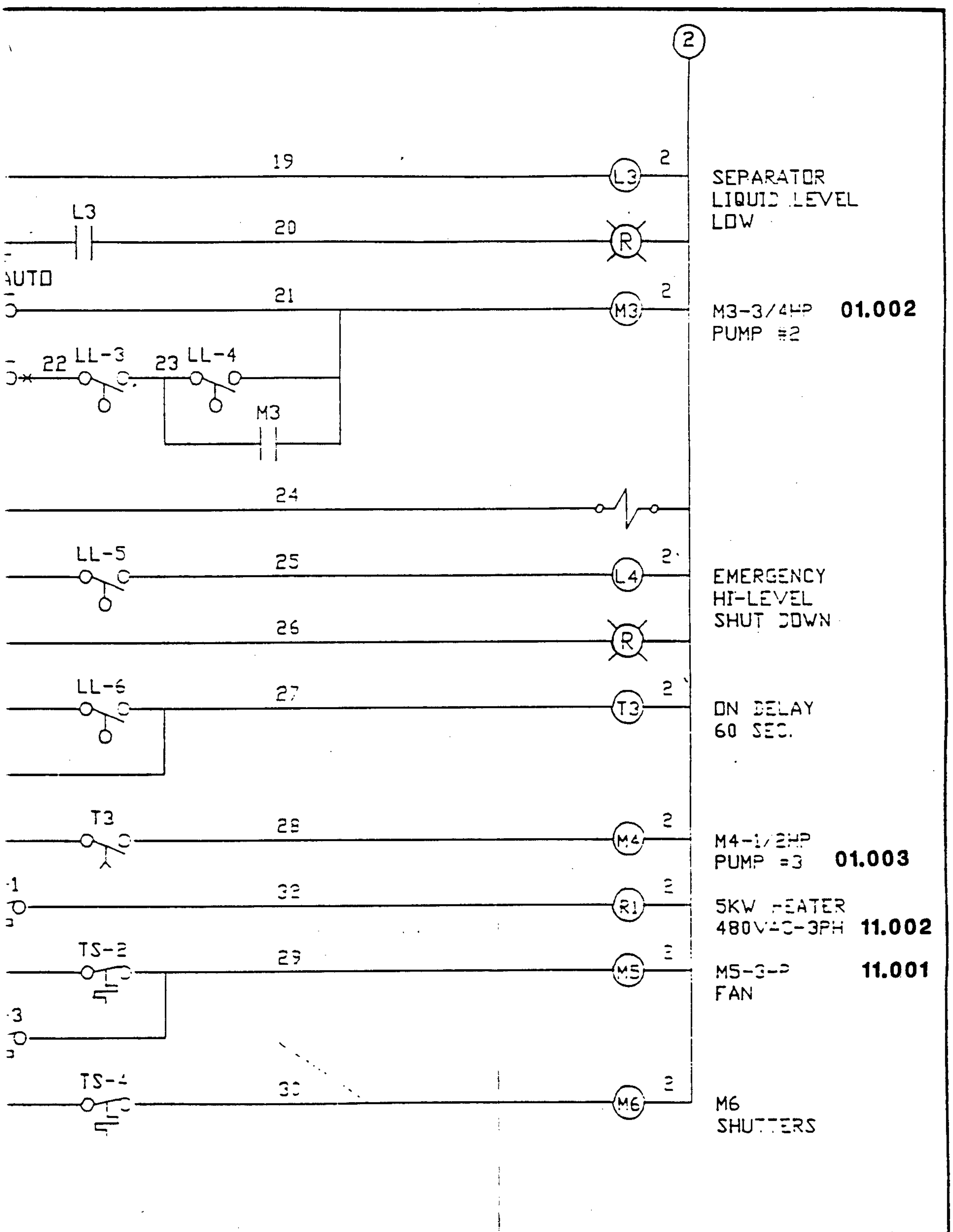
TS-2
29
TS-3
TS-4
30
VA
EL
JA
GR
DWG
A



VAPOR EXTRACTION ELECTRICAL SCHEMATIC	
JACOBS ENGINEERING GROUP INC.	
DWG # 804-001	DATE 08-04-92
AIR COMPONENTS, INC.	

INTERVAC CORPORATION
125 RAWSON ROAD
VICTOR, NEW YORK 14564
(716)924-7080 - FAX 924-7080

SYSTEM SERIAL NUMBER: 92052544

SYSTEM MODEL NO: PSW 1000/1-1FR

DISTRIBUTOR: AIR COMPONENTS & ENG. INC.
939 KEN-O-SHA IND. DR. S.E.
P.O. BOX 9385
GRANDS RAPIDS, MI 49509-9385

PHONE: (616)452-3188

FAX: (616)452-0393

SYSTEM CAPACITY: 1000 ACFM AT: 15 IN HGV

PUMP MODEL NUMBER: PLM 73/5C-F

MOTOR: 75 HP 1200 RPM

ENCLOSURE: XP, CLASS1 GROUP C&D

SEAL FLUID: WATER PROCESS FLUID: AIR

STARTER DATA: NONE

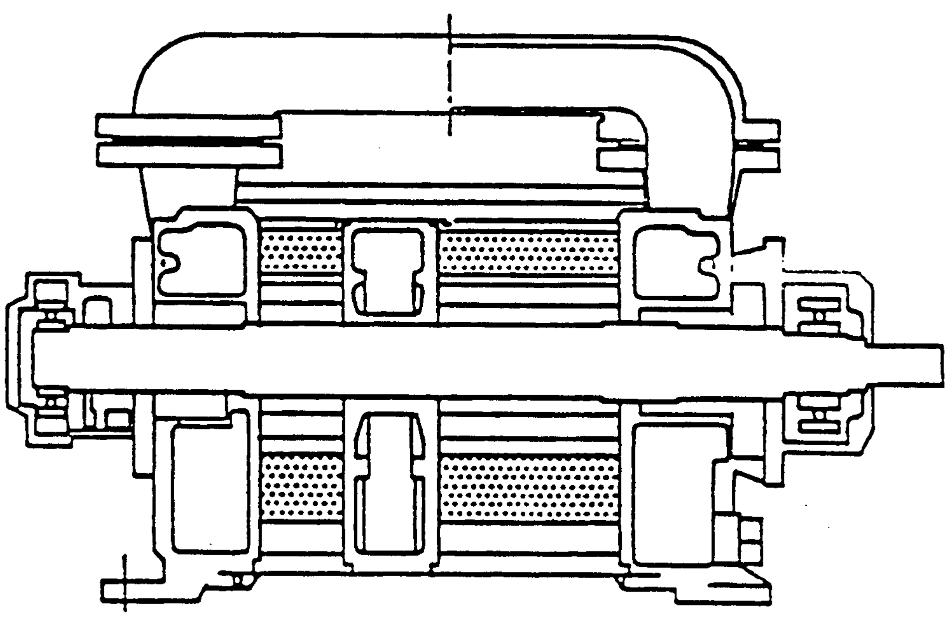
NEMA: NONE SERVICE: NONE

LEAD/LAG AUTOMATIC OPERATION: NONE

FREQUENT START PROTECTION: NONE

GENERAL INSTALLATION, OPERATION, AND MAINTENANCE INSTRUCTIONS

WATER SEALED SYSTEMS
(NO RECOVERY, PARTIAL RECOVERY, FULL RECOVERY)



Supercedes 805, 1-9 8/14/85

TABLE OF CONTENTS

INSTALLATION, OPERATION AND MAINTENANCE MANUAL

INTRODUCTION

This manual contains instructions for the installation, operation and maintenance of your Intervac liquid ring vacuum pump system. It has been designed to provide safe and reliable service. However, since it is a piece of rotating equipment, the operator must exercise good judgement and proper safety practices to avoid damage to the equipment or personal injury. The instructions in this manual are intended for personnel with a general training in operation and maintenance of vacuum pumps.

SAFETY

It is assumed that your safety department has established a program based upon a thorough analysis of industrial hazards.

It is important that due consideration be given to these hazards which arise from the presence of electrical power, hot oil, or other liquids and toxic gases. Proper installation and care of protective devices is essential.

In the following safety procedures you will encounter the words WARNING, CAUTION, and NOTE. They are intended to emphasize certain areas in the interest of personal safety and satisfactory pump operation and maintenance. The definitions of these words are as follows:

WARNING: An operation procedure, practice, etc. which, if not correctly followed, could result in personal injury or loss of life.

CAUTION: An operating procedure, practice, etc. which, if not strictly observed, could result in damage or destruction of equipment.

NOTE: An operating procedure, condition, etc. which is essential to highlight.

These safety procedures are to be used in conjunction with the installation, operation and maintenance instructions contained in the system manual.

INSTALLATION

NOTE: The design of plant piping systems, foundations, and other areas of system design is the responsibility of others, not Intervac Corporation or its representatives. Data and comments are offered as an aid, but Intervac cannot assume responsibility for the design and operation.

We recommend that the customer consult a specialist skilled in the design of foundation, piping, and equipment location so as to supplement and interpret Intervac Corporation's information and to insure a successful installation.

WARNING: Install, ground, and maintain equipment in accordance with the National Electric Code and all applicable federal, state, and local codes.

CHECK UPON ARRIVAL

The unit should be inspected immediately upon arrival, and any irregularities arising due to shipment should be reported to the carrier.

PREPARATION

Read this manual and other literature provided. If questions arise, consult the distributor or the factory.

Verify that the proper utility services required to operate the equipment are available. Among these are the electrical supply, voltage, current, number of phases, the water supply temperature, flow capacity and quality, and drain size and capacity.

LOCATION

Install the vacuum system in an accessible place, as close as possible to the vacuum use area. Allow adequate space for operation as well as for maintenance operations involving dismantling and inspection of parts.

Consideration must be given to environment. Proper ventilation is necessary, and extremes of dampness or temperature should be avoided.

GENERAL DESCRIPTION AND PRINCIPLE OF OPERATION

GENERAL DESCRIPTION

Liquid Ring Type Vacuum Pumps

The rotary impeller is located eccentrically within the pump casing. The liquid ring, therefore, acts as a piston. Both single and two stage pumps are available in a wide range of sizes.

The operating ranges, when using water at 60 degrees F. as the seal liquid, are:

- Single stage pumps: down to 25" Hg. vacuum (125 TORR suction pressure)

- Two stage pumps: down to 29" Hg. vacuum (25 TORR suction pressure)

The standard materials of construction are suitable for handling air and other non- corrosive gases using water as the seal liquid. Other materials can be substituted for special aplications.

PRINCIPLE OF OPERATION

Figure # 1 shows a cross section of a liquid ring vacuum pump. The impeller is cylindrical in shape with a mulitiude of blades and is located eccentrically in the impeller housing which is partially filled with the sealing liquid, normally water. A portplate with suction and discharge openings is located on each side of the impeller cell.

As the impeller rotates the centrifugal force flings the sealing liquid outwards where it forms a liquid ring which follows the contour of the impeller housing. Start at point "A" the impeller cell is completely filled with the sealing liquid.

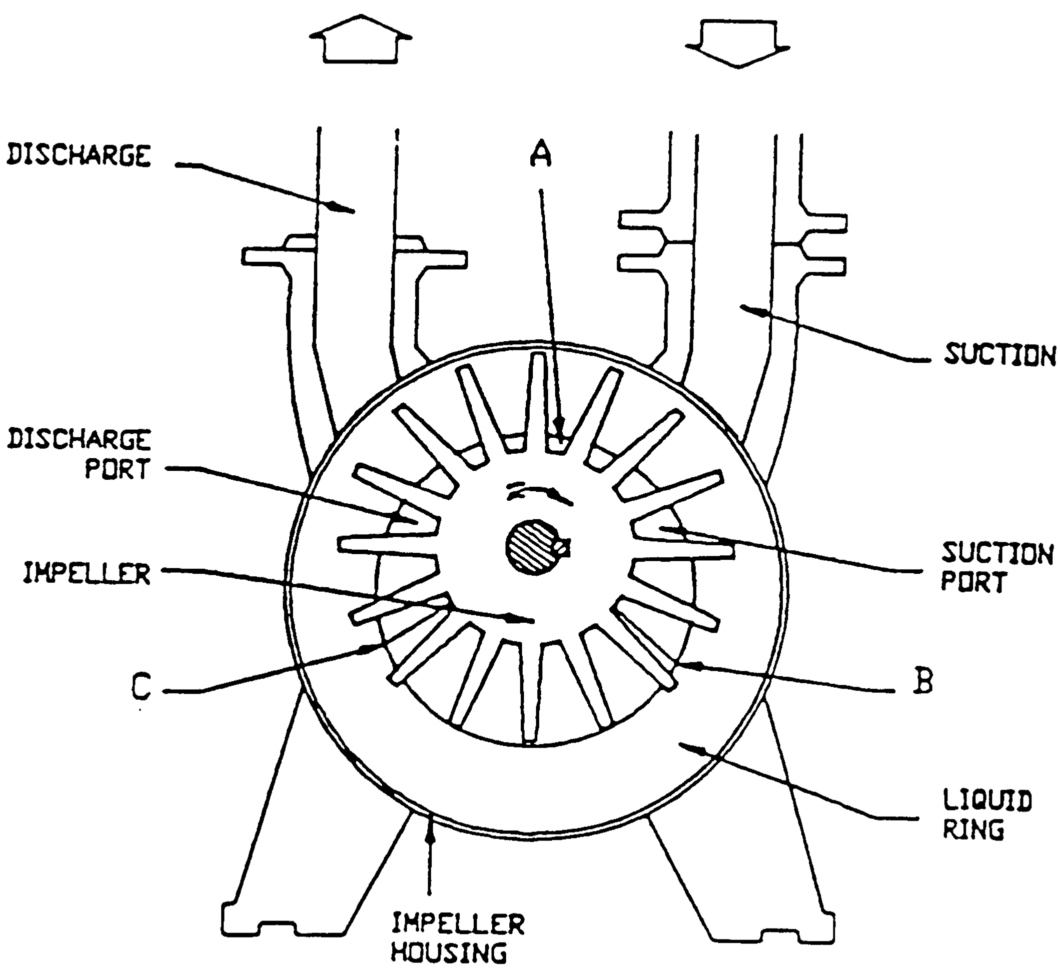
As the impeller advances, the liquid in the cell recedes and creates a vacuum in the empty space, which draws in the air or gas through the suction port. Continued rotation increases the gas volume in the impeller cell until the end of the suction cycle at point "B".

From point "B" onwards, the liquid is gradually forced back into the impeller cell, compressing the gas trapped in between, until at point "C" the compressed gas is expelled through the discharge port together with part of the sealing liquid.

The complete cycle can be compared with a piston in a cylinder where the piston is the liquid ring and the impeller cell is the cylinder. The heat generated by the pump during the compression cycle is dissapated into the liquid ring.

A fresh supply of cool liquids is continually introduced into the pump through a separate sealing liquid supply opening. The amount of cooling liquid added is synonymus with that discharged through the discharge port together with the compressed gas.

Figure 1



PUMP INSTALLATION INSTRUCTIONS

Carefully unpack the pump, taking care not to damage or misalign the pump. For pump and motor units mounted on a baseplate, lift by the baseplate only. Do not attach slings or hooks to the pump or motor. This can cause misalignment. Do not attempt to run the pump until the installation work is complete as detailed in this manual. <u>DO NOT</u> run pump without sealant liquid.

A. Preservation Procedures

Pumps are protected with a water soluble preservative which should be flushed from the pump, if other than water is utilized on a closed loop system. The location of the installation or storeage of the unit should be such that the liquid is not allowed to freeze.

B. Foundation

The foundation should be sufficiently rigid and substantial enough to absorb any system vibration and to permanently support the baseplate at all points. It should be strong enough to support one and a half times the weight of the unit.

Leveling the Baseplate

Place the unit on the foundation and level the baseplate. Use a machinist's level to determine the levelness.

Pull the foundation bolts down so they are snug and re-check with level. Adjust if needed.

Grouting

<u>NOTE:</u> Do not grout until the unit has been leveled.

Build a dam around the baseplate and push or squeeze grout under the frame with a trowel.

It is recommended that the baseplate be completely grouted.

C. Direct Coupled Units

Correct alignment of the pump and motor is of the utmost importance. Pump/motor combinations are aligned at the factory, but baseplates may be distorted in shipment, and misalignment may occur due to unequal tightening of the foundation bolts or pipe strain. It Is therefore essential that alignment is checked before the unit is put into service.

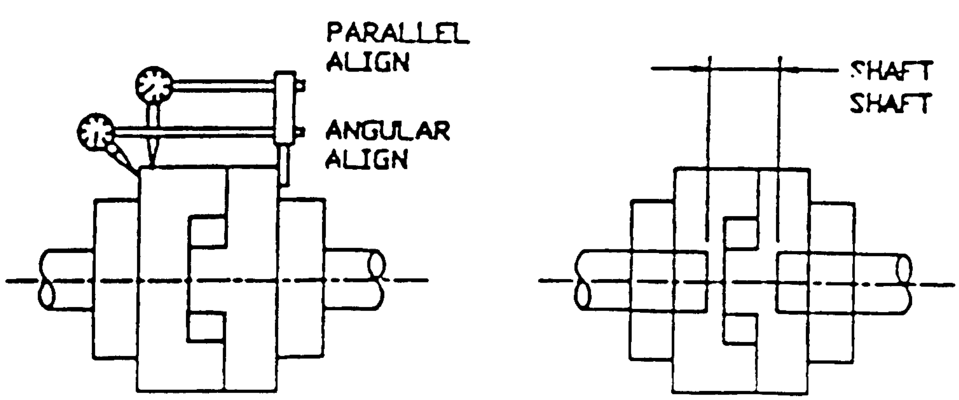
Both angular and parallel alignments should be within .005 inch, total indicator runout. Monoblock units do not require field alignment.

Drive Coupling

Drive coupling hubs should be checked and maintained for tightness of set screws and proper spacing. The flexible element must be allowed approximately 1/16" of free axial movement.

FIGURE 2

LOVEJOY COUPLING SIZE	PARALLEL X INCH	ANGULAR Y INCH	SHAFT/SHAFT INCH
AL-095	.005	.005	1/2'
AL-100	.005	.005	3/4'
AL-110	.005	.005	7/8'
AL-150	.005	.005	1'



D. V-Belt Coupled Units

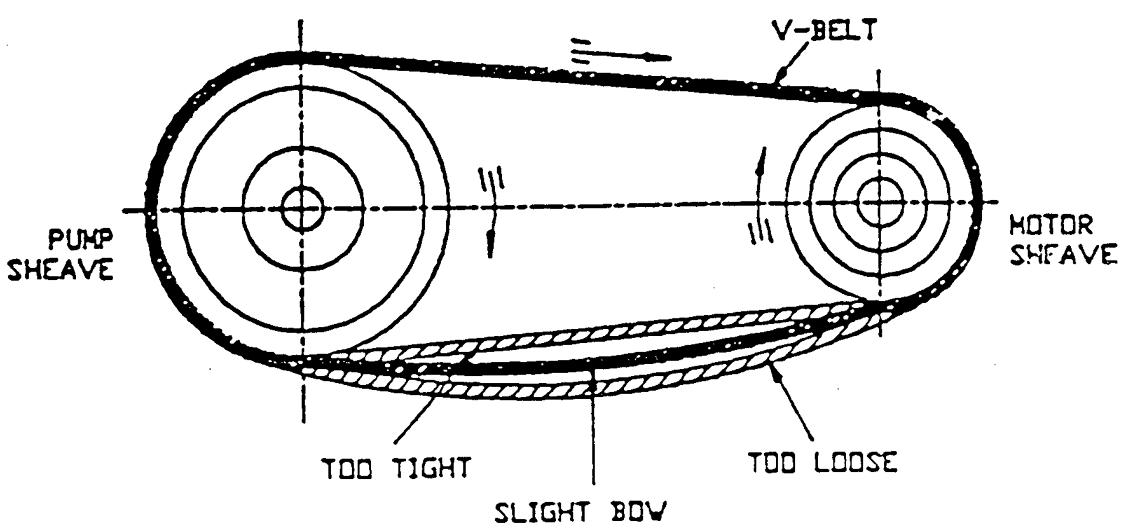
For the pumps utilizing V-belt drives, make sure the sheaves are properly installed and aligned before attempting to tension the drive. The V-belts should be placed over the sheaves and in the grooves without forcing them over the sides of the grooves. The tensioning steps 1,2, and 3 can be used for all types of V-belts, all cross sections and number of belts, and all types of construction.

1. With all belts in their grooves, adjust centres to take up the slack until they are fairly taut.

2. Start the drive and continue to adjust until the belts have only a slight bow on the slack side while operating <u>with load conditions.</u>

3. After several days of operation, the belts will seat themselves in the sheave grooves. Further tensioning may be necessary, such that the drive shows a slight bow in the slack side. Insufficient tension is often evidenced by slipping (squealing) at start-up. If the unit is idle for an extended period of time, the tension on belts should be removed. Excessive heat (140 degrees and higher) should be avoided, as belt life is shortened since the rubber is overcured. Belts should never be mixed or switched from one groove to another on the sheaves and <u>belt dressing never should</u> be used. <u>Belts should be replaced with a matched set.</u> Sheaves should remain free of oil and grease. Consult the drive manufacturer for more specific information.

FIGURE 3



E. SEAL LIQUID PIPING ARRANGEMENTS

The working principle of the liquid ring pump is dependent upon a continuous supply of clean seal liquid which is normally water. The seal liquid enters the pump through a connection on the casing and is discharged from the pump, along with the gas. There are three basic seal liquid arrangements that can be used for vacuum pump applications.

All of these arrangements have four basic elements:

1. Source of seal liquid (from water main or reservoir).

2. Regulating device to control flow of liquid.

3. Means of stopping flow when pump is shut off. (manually or with solenoid valve)

4. A means of separating the gas-liquid exhaust mixture.

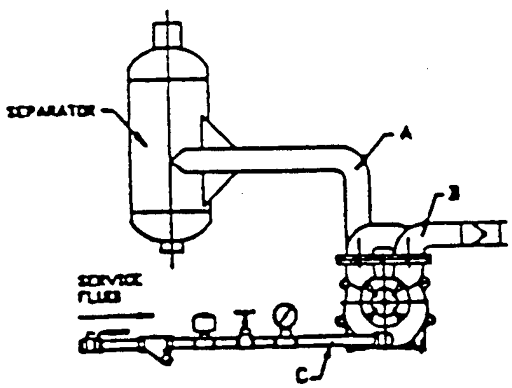
1. Seal Liquid: Once Through -No Recovery
(Arrangements are shown on Figure 4)

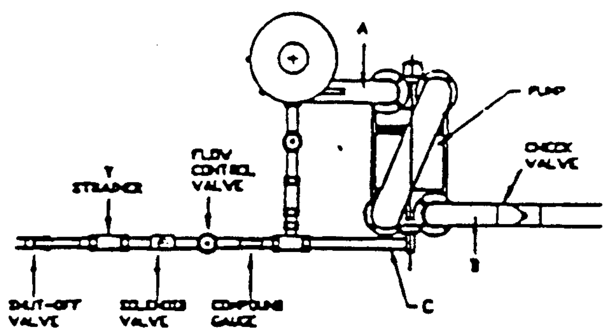
VACUUM PUMPS

Seal liquid is taken directly from a main and supplied to the pump. The liquid is separated from the gas and wasted to a drain. No recirculation or recovery takes place. This is the most common arrangement and can be used where seal liquid conservation or contamination is not a concern. An automatic solenoid valve provides for flow of seal liquid simultaneously with motor-pump operation (i.e. upon motor stopping, the valve closes preventing the casing to be filled with seal liquid).

With a manual seal liquid shut off valve, it must be CAUTIONED to open valve immediately after starting motor and close valve immediately before turning motor off.

FIGURE 4





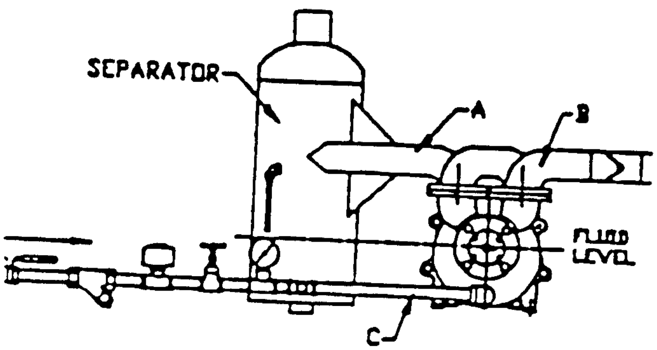
A = Connect to pump discharge
B = Connect to pump suction
C = Connect to pump service liquid
(Refer to Fig. 7 for specific location of pump connection)

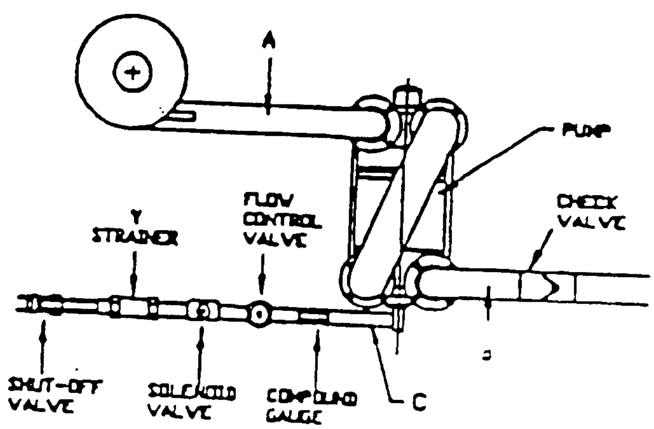
2. Seal Liquid: Partial Recovery of the seal liquid (Arrangements are shown on Figure 5)

Vacuum Pumps

The seal liquid enters and leaves the pump in the same mannor as with the once through arrangement. A portion of the seal liquid is recirculated back from the separator tank to the pump. The remainder is discharged from the separator and wasted to drain. The fresh make-up seal liquid is introduced in sufficient quantit to maintain proper temperature essential to good pump performance. This type of arrangement is used where seal liquid conservation is important (up to 50%, reduction in fresh water consumption possible, and if other than water is utilized, the consumption can be reduced more than 50%, depending upon the fluid vapor pressure and temperature). The seal liquid level in the separator should be at, or slightly below, the centerline of the pump shaft.

FIGURE 5





A = Connect to pump discharge
B = Connect to pump suction
C = Connect to pump service liquid
(Refer to Fig. 7 for specific location of pump connection)

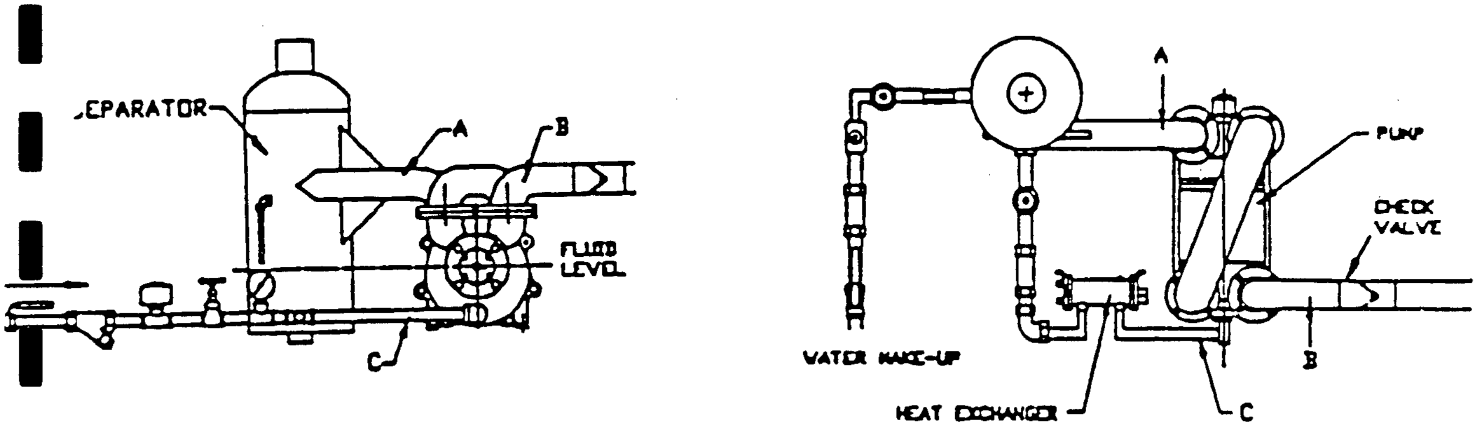
3. Seal Liquid: Full Recovery of the seal liquid
(Arrangements are shown on Figure 6)

Vacuum Pumps

This arrangement provides for total recirculation of the seal liquid. A heat exchanger is added to the system to remove the heat of compression, friction, and condensation from the seal liquid before it is re-introduced back into the pump. This heat exchanger may be of the shell and tube, or plate and frame design. A circulating pump is normally installed for prolonged operation at suction pressures above 300 TORR or when suction pressure varies during cycling operations.

The seal liquid level in the separator/recirculation tank should be at, or slightly below, the centerline the pump shaft. Provisions may also be made for high level overflow and low level make-up on total recovery systems. This will help prevent starting the pump with a full case of water, which could overload the pump and motor.

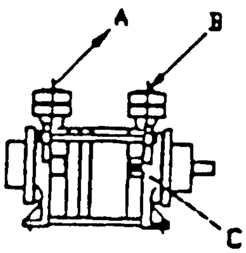
FIGURE 6

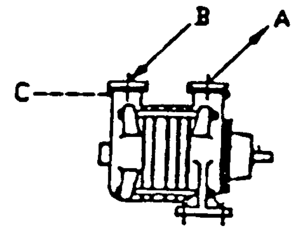


A = Connect to pump discharge
B = Connect to pump suction
C = Connect to pump service liquid
(Refer to Fig. 7 for specific location of pump connection)

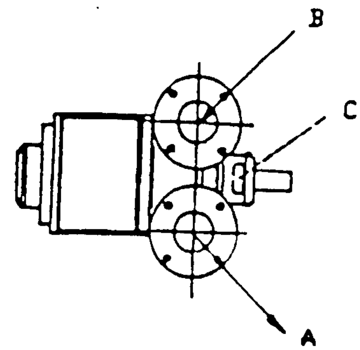
VARIOUS PUMP CONFIGURATIONS

FIGURE 7





PL - PLC 10/1

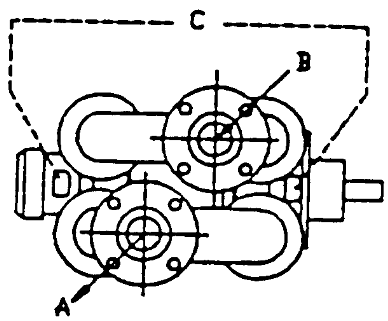


PLM - PLMC 52/2

PLT - PLTC 3103/1
PLT - PLTC 3106/1
PLT - PLTC 3203/1
PLT - PLTC 3206/1

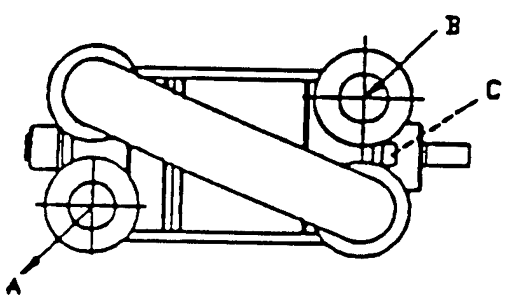
PLM - PLMC 31/5
PLM - PLMC 32/5
PLM - PLMC 33/5

PL - PLC 31/5
PL - PLC 32/5

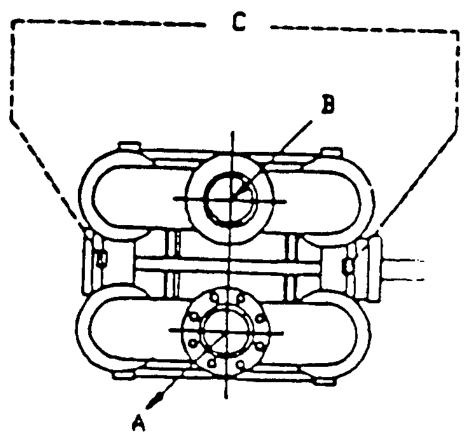


PLM - PLMC 42/5

A=Connect to pump discharge
B=Connect to pump suction
C=Connect to pump service fluid



PL 41/5	PL 61/2
PL 42/5	PL 62/2
PL 51/2	PL 71/5
PL 52/5	PL 72/5
PL 53/2	PL 73/5



PLM - PLMC 53/2
PLM - PLMC 53A/2
PLM - PLMC 61/2
PLM - PLMC 62/2
PLM - PLMC 72/5
PLM - PLMC 73/5

F. Pump Draining

When pumps are properly installed, as indicated in section E, the water level within the pump itself should be automatically set at shaft centerline or below every time the pump stops therefore no further draining should be required.

However, Intervac Vacuum Pumps are provided with additional connections at about the shaft centerline which may be fitted with an automatic drain valve; also the two stage pumps are fitted with a manual drain valve (or air bleeding valve depending upon use). All pumps are also fitted with casing draining plugs which would allow complete drainage of the pump.

G. Shaft Seals

Intervac Pumps do not require additional liquid control for the shaft sealing. The pump is fitted with mechanical seals and a suitable liquid supply is provided to the seals via the pump internal passages.

H. Piping

1. SUCTION AND DISCHARGE

Prior to installation, check that all protective inserts fitted in the gas and service liquid connections of the pump are removed.

Piping connected to the pump must be installed without imposing any strain on the pump. Improperly installed piping can result in misalignment, rubbing of internal parts, etc. Use flexible connectors when necessary.

Piping should be cleaned properly before installation and at least of the same size as the corresponding pump connections.

It is recommended that a temporary screen be installed in the inlet to the pump unit at first start-up to protect the unit against carry-over of pipe debris and welding slag. This screen can be removed after the initial run in period.

If the possibility exists that the pump inlet can become closed during operation, it will be essential to install some type of vacuum relief so that air can enter the system. NEVER RUN A PUMP WITH SUCTION CLOSED. A check valve suitable for vacuum service and providing a minimum of resistance must be installed in the suction line as close to the pump as possible, to prevent backflow of the process gas and sealing liquid into the system when the pump is stopped.

The discharge piping from the pump must be sized and installed in such a way that no back pressure is created. It is recommended to limit the vertical height of the discharge piping to a maximum of 24" above the pump flange prior to separating the gas and sealing liquid.

NOTE: The discharge line from the separator/reservoir must be vented outside the building, to avoid any contamination of the ambient inside air by any toxic gasses drawn into the system and discharged through the discharge opening on the separator.

2. SEALING LIQUID SUPPLY

The principle of the liquid ring vacuum pump is dependent upon a continous supply of cool, clean sealing liquid, normally water, which enters the pump through the sealing liquid inlet connection on the suction side of the pump and is discharged together with the compressed gas. The sealing liquid entering and leaving the pump also serves to carry away the heat of compression imparted to the liquid ring during the working cycle. With the proper quantity of sealing liquid supplied to the pump and no additional heat load from condensation of process vapors, the temperature rise across the vacuum pump will usually be limited to approximately 7 degrees Farenheit when using water as the sealing liquid.

For optimum pump efficiency, it is important to supply the correct amount of sealing liquid to the pump. Refer to the individual pump performance curves and tables for the correct quantity.

Pump performance data (as published) is based on the use of 60 degree Farenheit (15 degree C) water as the sealing liquid. When operating with water of higher temperature, a drop in capacity must be expected.

An adequate supply of good quality water must be available to meet the system requirement. The following data serves as a guideline for the water supply:

Pressure	min.	20	PSI
Water hardness	max.	200	ppm
Dissolved solids	max.	200	ppm
Chlorides	max.	10	ppm
pH	min.	7	

When supplied as a system from Intervac, the sealing liquid supply line components may be arranged in a number of ways. Refer to the schematic supplementing this manual, which pertains to your particular model.

If you have purchased a bare shaft pump and/or intend to use a sealing fluid other than water or one supplied by Intervac, consult your local distributor or Intervac for the recommended components and arrangement.

I. Electrical Requirements

Standard induction motors are suitable for driving Intervac Liquid Ring Pumps. Starting loads are low so that an across the line starter is normally employed for motors up to 100 horsepower. On larger motors, reduced voltage starting may be used, especially where the plant power supply is limited.

It is recommended that a motor controller with overcurrent protection of the heater or fuse type be used. The full load current rating, stamped on the motor nameplate, should be used in making the selection for protection rating. A disconnect switch should also be installed between the motor controller and plant power.

After the electrical work is completed the motor should be started to check rotation. First, turn the pump by hand to see that it rotates freely. The direction of rotation is marked by an arrow on the pump. Fill the pump casing halfway with seal liquid and then switch on the motor to check for rotation. If the direction is wrong, reverse any two of the three motor leads and recheck.

It is recommended that 115 volts, single phase supply be used for control circuits. Items such as solenoid valves, vacuum presure switches, level controllers, alarms, etc. should be supplied with only 115 volts to comply with electrical safety code requirements.

J. Accessory Items

There are many accessory items associated with Liquid Ring Pumps. These can be supplied with the pump from the factory or by others in the field. The particular application requirements, model of operation, and type of control scheme desired, dictate the necessity of the various items, however, the following list covers some of the more commonly used accessory items.

1. Check Valve - Used to prevent backflow of gas and seal liquid to process when the pump is stopped. Swing-check type or equal valve must be installed horizontally. An inlet elbow can be provided to adapt vertical pump inlet to accept horizontal inlet check valve.

2. Inlet Vacuum Relief Valve - Used to protect the pump from cavitation and to control suction pressure to a certain degree. When the pump capacity exceeds the System's flow requirements at a predetermined vacuum level, then the valve will open and bleed in atmospheric air or process gas (if connected back to pump discharge side).

3. Flexible Connector - Used for slight misalignment between pump and process or if a minimal amount of expansion is anticipated.

4. Inlet Vacuum Control Valve - Used to control system by bleeding in atmospheric air or process gas (recirculated back from pump discharge). Pneumatically operated diaphram valves are required to achieve fine degree of control.

5. Inlet Vacuum Gauge - Used to indicate vacuum at pump inlet. Normally it is mounted directly ahead of pump suction.

6. Sealant Shut-off Valve - Used to manually stop flow of sealant to pump.

7. Strainer - Used to filter out solid particles from sealant.

8. Sealant Flow Control Valve - Used to control sealant flow rate to the pump. Normally a globe valve is used, but other types of flow control valves can be used.

9. Compound Pressure Gauge - Used to indicate pressure at inlet connection of sealant piping to pump. Approximate flow rates can be established by maintaining proper pressure at sealant connection to pump. (See Operating Instruction Section).

10. Discharge Separator Tank - Used to separate sealant liquid from discharged gas stream coming out of pump. This separator tank can either be a floor mounted design, base plate mounted with pump, which is for partial and total recovery systems, or a type which is supported by the discharge piping (used on once through systems).

11. Solenoid Valve - Used to automatically stop-start flow of seal liquid to pump.

12. Sealant Circulating Pump - Used to recirculate sealant in total recovery systems. It is required when the pump operates for prolonged periods above 300 TORR or when suction pressure varies during cycling operations.

13. Heat Exchanger - Used to remove heat from recirculated sealant.

14. Atmospheric Air Ejector - Used to provide a suction pressure lower than pump is capable of operating alone. May be added to a two stage pump to provide an inlet pressure as low as 3 TORR. The operation of the air ejector is similar to that of steam ejectors. Atmospheric air or recycled gas from separator discharge is used as the motive force for compressing the process gas from system design pressure up to the inlet pressure of the liquid ring pump. To inhance pumping capacity above 30 TORR, a motive air shut-off valve can be added. To achieve full pump capacity above 30 TORR, a bypass can also be added.

OPERATING INSTRUCTIONS

A. SEAL LIQUID

1. FLOW RATES - Depend upon the type of sealant arrangement used, size of pump, and allowable temperature rise through the pump. Flow rates of water at 60 degrees F. for standard pumps at standard conditions are given on the Liquid Ring Vacuum Pump performance curve insert sheet.

Standard flow rates result in approximately 10 degrees F. rise in temperature for a single stage, and 12 degrees F. rise for a two stage through the pump when handling dry air. Condensible vapors in the gas stream add heat to the seal liquid. This will result in a slightly higher temperature rise through the pump.

Seal flow rates and the temperature rise are important because of the effect on pump performance. Too much seal will result in excessive horsepower requirements.

2. FLOW CONTROL - A regulating valve is used to control flow of sealant to the pump. A compound gauge is installed between the regulating valve and pump. The regulating valve should be set so that the reading on the compound gauge will be within 5" to 10" Hg. Vacuum for two stage pumps. On single stage pumps it is necessary to adjust the regulating valve to obtain approximately 3 to 5 PSIG supply pressure to the pump casing.

For partial recovery systems, the fresh make-up seal flow can be adjusted to obtain the highest temperature rise through the pump permissible to still achive the vacuum necessary for the process. This can be accomplished by sensing the sealant discharge temperature and regulating the sealant flow control valve on the fresh cool sealant make-up line.

Another procedure that can be used to establish the minimum seal flow required is with the pump operating at the desired vacuum on process, slowly reduce the flow of seal liquid until the suction pressure begins to fluctuate and then gradually increase the flow until the suction pressure again stabilizes. This setting can be used as long as the temperature rise through the pump remains reasonable (40 to 50 degrees F. maximum) and all other operating conditions remain constant.

3. HARD WATER - If hard water is used as a seal liquid, scale deposits cause by the precipitation of salt will occur. This will vary with the nature of the seal fluid temperature at which it is used. Scale deposits on the working surface of the pump will cause an increase in absorbed power, wear of the working parts, and may ultimately cause seizure of the pump. It is advisable to check hardness of the water and/or fluid in the pump.

If no alternatives to using hard water are possible, it may be necessary to use descaling compounds to remove deposits; or from time to time, dismantle the pump and strip off the encrusted salts.

B. Start-Up Procedures

WARNING: The unit must not be operated unless coupling guard is in place. Failure to observe this warning could result in personal injury.

WARNING: DO NOT attempt any maintenance, inspection, repair or cleaning in the vicinity of rotating equipment. Such action could result in personal injury.

INITIAL START UP PROCEDURE

1. Verify that the electrical power to the equipment is off.

2. Check the drive coupling alignment. (See Section C page 6). Adjust the driver if necessary. On monoblock units the alignment is preset.

3. Check the drive coupling hub spacing. The flexible element should be allowed approximately 1/16" of free axial movement. Adjust if necessary. Tighten setscrews.

4. Rotate the pump by hand to ensure that it turns freely. During the time between manufacture and start-up, a slight film of rust may form on the port plates, causing the pump to be hard to turn. If this is the case, fill the pump with a rust inhibitor and wait until it can be turned by hand. Drain the pump.

5. Fill the pump with clean sealing liquid up to the shaft level. Do not start the pump when the liquid level is above the shaft level, as the increased starting torque can cause damage to the pump internals and/or the driver.

6. It is recommended that a temporary screen be installed in the suction line of the pump for the first several hours of operation to remove any foreign assembly material, pipe scale, slag, etc.

7. Reinstall any safety guards or covers that may have been removed.

8. Open valve in suction line. Never start a pump with a closed inlet.

9. Verify that all valves required for operation are open (sealing liquid, cooling water, etc.)

10. Turn on the electrical power to the equipment. Verify that all phases are energized, and that the voltage is correct.

11. Check the driver rotation by jogging it for a period of less than one second. Correct direction of rotation is indicated by an arrow on the pump casing. Normal direction is clockwise facing shaft.

12. Start the driver and if necessary, adjust the sealing liquid flow for optimum performance. Units fitted with a compound gauge and a manual regulation valve should have the valve adjusted so that the gauge reads per Section (2) on Page (18).

13. Check the temperature of areas such as the bearing housings, pump and motor casings, and discharge piping for unusually hot spots.

14. Check that the motor current draw is within specifications.

MAINTENANCE

Intervac liquid ring vacuum pumps require very little attention or maintenance provided the units are installed properly.

MAINTENANCE SCHEDULE

AT FIRST 50 HOURS OF OPERATION

1. Clean any filters/strainers associated with the system to remove any foreign assembly material, pipe scale, etc. Remove temporary inlet screen fitted at start-up.

AT EVERY 1000 HOURS

1. Clean filters and strainers.

AT EVERY 3000 HOURS

1. On those vacuum pumps with grease fittings, grease the bearings. Use a moisture resistant lithium based grease of number 2 consistency. Typical products are Texaco Premium RB, Chevron SR1 # 2, and Esso Ronex MP. DO NOT OVERGREASE.

2. Check condition of drive coupling. Service if necessary.

3. On vacuum pumps fitted with external seal flush tubing, check the tubing and related porting for restriction. Clean/replace if necessary.

C. Shut-Down Procedures

1. Shut off seal liquid.

2. Stop motor drive.

3. Close all suction and discharge valves.

4. Protect pump from freezing. If this is not possible, drain pump completely or fill wiith anti-freeze.

D. Cavitation

Cavitation is recognized by a characteristic metallic or grinding noise inside the pump. It is caused when the pump suction pressure is too close to the vapor pressure of the seal liquid. If the seal liquid temperature rises such that the corresponding vapor pressure closely approaches the total suction pressure, then cavitation will occur.

When cavitation takes place, vapor bubbles form and collapse within the liquid ring. This is detrimental to the surfaces of the impeller, side plate, and casing. The cavitation shock force causes erosion by tearing away metal particles and deforming soft materials. Damage can be especially severe in a corrosive condition.

Cavitation is prevented by bleeding air into the pump casing. Vacuum relief valves can be fitted in the suction piping for this purpose. For two stage pumps, there is a manual attenuation valve between stages, which can be used to decrease the cavitation when opened.

If the problem is not a low flow of non-condensible gases, then the seal liquid temperature should be checked. With the proper temperature, the operating vacuum can be increased. Ultimately, the vacuum at which the pump can be operated is governed by the vapor pressure of the seal liquid.

E. Trouble-Shooting

Intervac pumps are simple in design and are ruggedly constructed. This provides for excellent reliability and long life when installed and operated properly. However, should you have difficulty in trying to resolve problems, refer to the following chart for suggestions to correct the problem. If the problem persists, do not hesitate to contact your representative.

TROUBLE-SHOOTING CHART

Problem	List if items to be checked
a) Reduced Capacity	1,2,3,4
b) Excessive Noise	5,6,7,8
c) High Power Consumption	6,7,9,10,11,12
d) Overheating	3,4,6,7,11,12
e) Vibration	6,12,13
f) Excessive Gland Leakage	14,15
g) Abnormal Bearing Wear	6,16,17
h) Mechanical Seal "Squeal"	18
i) Shaft Will Not Turn or Partially Seizes	12,19,20

Reason	Solution
1. Speed to low	Check voltage and belt tension
2. Leak in suction line	Repair
3. Seal liquid temperature too high	Check coolant flow and heat exchanger
4. Insufficient seal liquid	Provide correct flow rate
5. Excessive or insufficient seal liquid	Provide correct flow rate
6. Coupling misalignment	Realign coupling
7. Defective bearing	Replace bearing
8. Cavitation	Open attenuation valve or reset vacuum relief for lower vacuum
9. Excessive seal liquid	Reduce flow rate
10. Excessive back pressure	Correct as necessary
11. Gland ring too tight	Loosen gland
12. Improperly mounted pump	Make sure surface is level and all feet are touching surfaces using shims, if necessary.

13. Pump not properly anchored	Anchor
14. Worn packing	Replace packing
15. Gland cooling liquid pressure too high	Reduce pressure
16. Strain on pump casing from connecting pipe work	Support connecting pipe work
17. Shaft finger missing	Replace finger
18. Insufficient lubrication	Check flow of coolant to seals
19. Scale from hard water	Descale pump
20. Foreign object in pump	Dismantle pump and remove

MAINTENANCE INSTRUCTION

A. Bearings

During assembly the bearings are pre-packed with high quality grease. The two shaft bearings should be lubricated after each 3000 hours running time using good quality bearing grease. The temperature of the bearings should not exceed 140 degrees F. (60 degrees C.). Overheating may be due to too much grease, misalignment of coupling, or a bad bearing. Replacement bearings can be obtained from your local distributor.

TABLE 1

BEARINGS

PUMP SERIES PL	PUMP SERIES TR	DIRECT COUPLED	BELT DRIVE	MECHANICAL SEAL
30	40	(x2)00012012-000	(x1)00012012-000 (x1)00012010-000	V=(x2)00011282-000
40	40	(x2)00012013-000	N/A	V=(x2)00011352-000 B=(x2)00011351-000
50	65	(x2)00012015-000	N/A	V=(x2)00011432-000 B=(x2)00011431-000
60	80	(x2)00012016-000	(x1)00012016-000 (x1)00012018-000	V=(x2)00011552-000 B=(x2)00011551-000
70	N/A	(x2)00012017-000	N/A	V=(x1)00011752-000 DE V=(x1)00011753-000NDE B=(x1)00011750-000 DE B=(x1)00011751-000NDE
3000	N/A	(x2)00012011-000	N/A	V=(x2)00011222-000 B=(x2)00011221-000

( ) = QTY
V = Viton
B = Buna
DE = Drive End
NDE = Non-Drive End

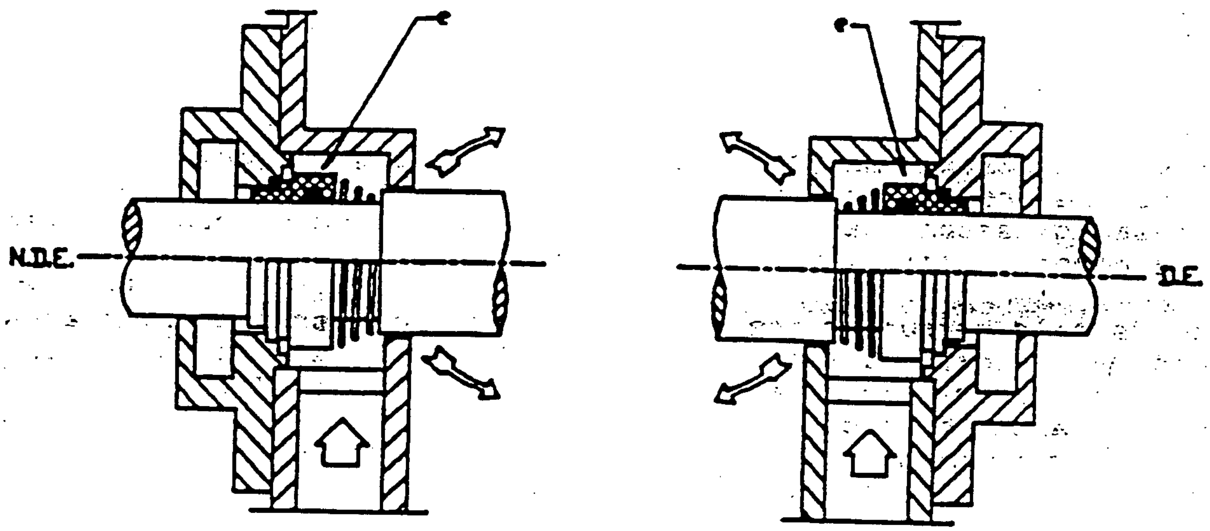
B. Mechanical Seals

This section pertains to pumps fitted with mechanical seals. Mechenical seals usually do not require maintenance unless there is visual leakage to the outside.

Seal replacement or repair is addressed in the "Disassembly and Assembly Instructions" for a specific pump series.

When handling mechanical seals always make sure that the working seal faces are well protected and clean from particles which may scratch these surfaces. Prior to installing the mechanical seals thoroughly clean the shaft surface edges, moisten shaft and seal o-ring elements with water, alcohol, or other clean liquids, to facilitate fitting of the seal over the shaft and in the seal housing.
<u>CAUTION</u>: NEVER RUN THE SEALS DRY.

(e: Mechanical seal)



C. Storage

The pump and/ or system is protected against corrosion for the period of shipment and installation only.

If the unit is not to be installed at once, find a clean, dry location for storage.

For long term storage, the pump should be flushed with a water soluable rust preventative.

WARRANTY AND LIMITATION OF LIABILITY

Subject to the terms and conditions set forth in General Terms of Sale, Intervac Corporation (the Seller) warrants products and parts of its manufacture, when shipped, and its work (including installation and start-up) when performed, will be of good quality and will be free from defects in material and workmanship. This warranty applies only to Seller's equipment, under use and service in accordance with Seller's written instructions, operating, maintenance and service of products, for a period of five (5) years on the pump and two (2) years on the balance of the system, and ninety (90) days on mechanical seals after date of shipment for all new products, and six (6) months for all rebuilt or remanufactured products which are not supplied under standard situations.

On warranty repairs, the warranty period will be either whatever time was left on the original warranty at time of removal or three (3) months, whichever is greater. Because of varying conditions of installation and operation, all guarantees of performance are subject to plus or minus 10% variation.

THIS WARRANTY EXTENDS ONLY TO BUYER AND/OR ORIGINAL END USER, AND IN NO EVENT SHALL THE SELLER BE LIABLE FOR PROPERTY DAMAGE SUSTAINED BY A PERSON DESIGNATED BY THE LAW OF ANY JURISDICTION AS A THIRD PARTY BENEFICIARY OF THIS WARRANTY OR ANY OTHER WARRANTY HELD TO SURVIVE SELLER'S DISCLAIMER.

All accessories furnished by Seller but manufactured by others bear only that manufacturer's standard warranty.

All claims for defective product, parts, or work under this warranty must be made in writing immediately upon discovery and, in any event within one (1) year from date of shipment of the applicable item and all claims for defective work must be made in writing immediately upon discovery and in any event within five (5) years on the pump and two (2) years on the system from the date of shipment thereof by the Seller. Unless done with prior written consent of Seller, any repairs, alterations or disassembly of Seller's equipment shall void warranty. Installation and transportation costs are not included and defective items must be held for Seller's inspection and returned to Seller's facility upon request.

Seller's warranty does not cover damage due to one or more of the following:

1. Abnormal wear and tear.
2. Abuse and unreasonable use.
3. Misuse or neglect.
4. Damage caused by equipment or system for which the product is used.
5. Damage caused by modification or repair not made or authorized by the seller.

THERE ARE NO WARRANTIES, EXPRESSED IMPIED OR STATUTORY WHICH EXTEND BEYOND THE DESCRIPTION ON THE FACE HEREOF, INCLUDING WITHOUT LIMITATION, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS.

After buyer's submission of a claim as provided above and its approval, Seller shall at its option either repair or replace its product, part, or work at a facility of its choice, or refund an equitable portion of the purchase price.

The products and parts sold hereunder are not warranted for operation with erosive or corrosive material or those which may lead to build-up material within the product quoted. The Buyer shall have no claim whatsoever and no product or part shall be deemed to be defective by reason of failure to resist erosive or corrosive action nor from problems resulting from build-up of material within the Unit.

Any improper use, operation beyond capacity, substitution of parts not approved by Seller, or any alteration or repair by others in such manner as in Seller's judgement affects the product materially and adversely shall void this warranty.

No employee or representative of Seller other than an officer of the Company is authorized to change this warranty in any way or grant any other warranty.

The foregoing is Seller's only obligation and Buyer's only remedy for breach of warranty, and except for gross negligence, willful misconduct and remedies permitted under the General Terms of Sale in the sections on CONTRACT PERFORMANCE, INSPECTION AND ACCEPTANCE and the PATENTS clause hereof, the foregoing is BUYER'S ONLY REMEDY HEREUNDER BY WAY OF BREACH OF CONTRACT, TORT OR OTHERWISE, WITHOUT REGARD TO WHETHER ANY DEFECT WAS DISCOVERED OR LATENT AT THE TIME OF DELIVERY OF THE PRODUCT OR WORK. In no event shall Buyer be entitled to incidental or consequential damages. Any breach of this agreement must commence within one (1) year after the cause of action has occurred and such action will be governed by the laws of the State of New York.

TERMS AND CONDITIONS

1. Prices - All prices are f.o.b. shipping point. Quotations are firm for 60 days and thereafter are subject to review and revision. All excise, sales, use and other similar taxes applicable to this order and required to be collected by the seller shall be added to the invoice unless appropriate exemption certificate is received.

2. **Acceptance and Cancellation of Orders** - No contract between the seller and buyer shall be deemed in existance until buyer's order has been accepted and acknowledged in writing by seller. Order placed may be cancelled, and shipment of goods made up or in process extended beyond the original delivery date, only with the seller's written consent, and upon terms which will equitably indemnify the seller.

3. Terms of Payment - The standard terms of payment are net cash 30 days from date of invoice.

4. Title - Title to all products and parts ordered and risk of loss shall pass to buyer upon their delivery to a carrier for shipment. Any claims for shortages or damages suffered in transit shall be submitted by the buyer directly to carrier.

5. Delays - Seller shall not be responsible for any defaults, damages, or delays in filling order caused by conditions beyond seller's control, including but not limited to Acts of God, strike, lock-out, boycott or other labor troubles, war, riot, flood, government regulations or delays of seller sub-contractors, or suppliers in furnishing materials or supplies due to one or more of the foregoing causes.

6. **Warranty** - Seller warrants products furnished hereunder to be free from defects in material and workmanship under normal use and service for a period of two years after the sale of the product by the seller. Seller's sole obligation under this warranty shall be to repair or replace any defective product or part thereof which is returned to seller's factory transportation charge prepaid within the period mentioned above, and which upon examination is proven to seller's satisfaction to be so defective. The warranty shall not apply to any product or part which has been subject to misuse, negligence, or accident. Seller shall not be responsible for any special, incidental or consequential damages and the warranty as set forth is in lieu of all other warranties either expressed or implied. Components purchased by seller are warranted by the original manufacturer, and the seller neither offers nor assumes responsibilities for the warranty of these components beyond that offered by the original manufacturer. Seller specifically excludes and and all warranties of merchantibility and of fitness for a particular purpose. Any alterations or repairs made without seller's written approval relieves seller of all responsibility. Mechanical shaft seals are warranted for 90 days from date of start-up or 12 months from date of shipment.

7. **Patent Liability** - Seller agrees to hold buyer and its customer harmless only against infringement of patents covering the material or part in the form sold by seller provided buyer or its customer, as the case may be, promptly notifies the seller of any claim or litigation and tenders the defense thereof to the seller. Buyer agrees to hold seller harmless for any liability of seller for infringement of patents by reason of manufacture according to design or by reason of incorporation of said part in a more comprehensive assembly than sold by the seller provided seller promptly notifies buyer of any claim or litigation and and tenders the defense thereof to the buyer. Seller grants no license, expressed or implied, other than the right of the the buyer to use the specific material or part in form delivered by seller.

8. **Rejections and Returned Material** - Claims for incorrect material must be filed in writing within 10 days from delivery at buyer's place of business. No material may be returned without first obtaining approval from the seller and no claim will be allowed or credit given fro material returned without such written approval.

9. **Service Calls** - The services of seller's representatives performed outside seller's plants are available when specifically covered by a separate service contract.

10. Buyer agrees to indemnify seller for, and hold seller harmless from, all costs and expenses incurred by seller, including, without limitation, costs of investigation, attorneys' fee, and amount paid in settlement or satisfaction of claims, procedings, or judgements, in connection with all claims and proceedings against seller based upon claimed defects in design in design in any item or items manufactured for buyer by seller to buyer's design and/or specifications.

11. Inspection - Buyer will inspect all goods purchased prior to or upon their delivery f.o.b. carrier; seller, including, without limitation, costs of investigation, attorneys' fees, and amounts paid in settlement or satisfaction of claims, proceedings, or judgements, in connection with all claims and proceedings agains seller based upon claimed defects in design in any item or items manufactured for buyer by seller to buyer's design and/or specifications.

12. Tools, Fixtures - Tools, fixtures, jigs, dies, etc. needed to provide the goods or services ordered are seller's property unless specifically purchased by buyer.

13. This sale is conditioned on the buyer's agreement that the terms and conditions set forth above shall be applicable to all orders accepted by seller, and shall cancel and supersede any terms and conditions whether oral or by purchase order forms submitted by the buyer. These terms and conditions are subject to modification only by the mutual agreement of the buyer and seller expressed in writing and shall be construed under the laws of the State of New York.

MASTER PARTS LIST

CODE	DESCRIPTION
106	SUCTION HOUSING
107	DISCHARGE HOUSING
109	INTERMEDIATE
110	IMPELLER CASING
110.1	IMPELLER CASING
114	INTERMEDIATE
137.1	PORT PLATE
137.2	INTERMEDIATE PLATE
137.3	INTERMEDIATE PLATE
137.4	PORT PLATE
140	INTERMEDIATE ELEMENT
140.1	INTERMEDIATE ELEMENT
147	MANIFOLD
183	SUPPORT FOOT
210	SHAFT
230	IMPELLER
230.1	IMPELLER
310	BEARING BUSH
310.1	BEARING BUSH
320	BALL BEARING
322	ROLLER BEARING
341	PEDESTAL
350	BEARING HOUSING
357	BEARING HOUSING
357.1	BEARING HOUSING
360	BEARING COVER
360.1	BEARING COVER
365	BEARING SHIELD
365.1	BEARING SHIELD
400	GASKET
400.1	GASKET
400.2	GASKET
400.3	GASKET
400.5	GASKET
400.8	GASKET
421	SHAFT SEAL
433.1	MECHANICAL SEAL
433.2	MECHANICAL SEAL
451	STUFFING BOX HOUSING
452	GLAND
458	LANTERN RING
461	GLAND PACKING
461.1	PACKING SEAL RING
471	MECHANICAL SEAL COVER
485	SPACER
504	SPACER
505	SHOULDER RING
505.1	SHOULDER RING
507	THROWER
521	SPACER SLEEVE

CODE	DESCRIPTION
524	SHAFT SLEEVE
542	THROTTLING BUSH
550	SHOULDER RING
554	WASHER
562	DOWEL PIN
636	GREASE FITTING
672	VALVE COCK
701	CIRCULATION PIPE
722	FLANGE PIECE
723	COUNTER FLANGE
724	BLANK FLANGE
731.1	FITTING
731.3	FITTING
731.4	FITTING
731.5	FITTING
731.6	FITTING
734	FITTING
735	FITTING
801	FLANGED MOTOR
861.1	COUPLING HALF
861.2	COUPLING HALF
867	COUPLING INSERT
900	SCREW
901.1	SCREW
901.2	SCREW
901.4	SCREW
901.8	BOLT
901.9	BOLT
902	STUD
902.1	STUD
902.3	STUD
902.4	STUD
903	PLUG
903.1	PLUG
903.2	PLUG
903.6	PLUG
903.7	PLUG
903.9	PLUG
905	TIE BOLT
914	SCREW
914.1	SCREW
914.2	SCREW
920	NUT
922	SHAFT NUT
922.1	SHAFT NUT
923	BEARING NUT
932	CIRCLIP
932.3	CIRCLIP
935	SPRING WASHER
940	SHAFT KEY
940.1	SHAFT KEY

NOTE: THIS CODE SHEET IS TO BE USED WITH PUMP CROSS SECTION DRAWING (SEE NEXT PAGE)

BULLETIN #0189-01

TO: ALL INTERVAC VACUUM SYSTEM USERS

FREQUENT START PROTECTION

If your vacuum system is equipped with a vacuum switch and a (hand-off-auto) switch, you have an automatic feature. When in the "Auto" mode, your vacuum pump(s) will turn on and off upon demand.

This is accomplished with the vacuum switch. Depending upon the settings (adjustable) of this switch, the pump(s) will turn on at a specific level of vacuum and turn off at a specific level.

If your set points on this switch are very close to each other and/or your demand (required vacuum) is substantially lower than capacity (ACFM - Absolute Cubic Feet Per Minute) of the system, the following may occur:

Your vacuum pump(s) could cycle on and off too frequently. This can lead to several problems: Premature failure of motor-to-pump coupling elements, loosening of couplings, fracturing of couplings, and possible mp and/or motor damage. The rule of thumb varies depending on the motor manufacturer, but for a good design a maximum of 3-5 motor starts per hour is common practice.

If your system is stopping and starting more than 5 times per hour, we recommend that you immediately make one of the following modifications:

1) Installation of a correctly sized vacuum relief valve. This valve would be installed at a pipe "tee", away from the pump inlet (i.e. at the vacuum receiver tank, or in the process piping close to the process.) This valve will create an artificial load on the pump and require it to run longer before satisfying the vacuum switch setting.

2) Installation of a time delay-off circuit to your control panel. Contact our service department for correct sizing. This circuit operates as follows:

The pump runs until the vacuum switch says that it is satisfied. Instead of shutting off the time delay relay overrides the vacuum switch and the pump will continue to run for the pre-set time on the relay. (Typical setting of 15-20 minutes.)

NOTE:

Please be advised that damages due to frequent starting will not be covered under Intervac's warranty.

TWO STAGE VACUUM PUMPS

Two-stage vacuum pumps are designed to operate continuously at 20"-29.5" Hg.
Single-stage vacuum pumps are designed to operate continuously at 0"-25" Hg.

If you are operating a two-stage pump below 20" Hg. without an interstage relief valve, you will have problems. This condition will cause overloading of the motor and premature failure of the pump by creating a high pressure differential in the interstage. The result could be a broken pump shaft and/or motor failure.

If you have this problem, there are two cures:

1) Install an interstage relief valve.

2) Replace the pump with a single-stage pump.

NOTE:

Please be advised that damages due to the operation of your two-stage pump out of range will not be covered under Intervac's warranty.

IF YOU HAVE ANY QUESTIONS CONCERNING THESE TWO SUBJECTS, NEED MORE INFORMATION OR REQUIRE ASSISTANCE IN PROPERLY SELECTING THE APPROPRIATE SOLUTION TO YOUR PROBLEM, PLEASE CALL INTERVAC CORPORATION AT 1-800-8487.

7/15/88

ADDENDUM TO INTERVAC WATER SEALED SYSTEMS

Intervac pumps are shipped from the factory with an anti-corrosive solution during the months of April - October and a 50/50 ethylene glycol solution November - March.

If for any reason your Intervac system is to be stored for a period longer than 30 days from date of shipment, you <u>must</u> follow these instructions:

1) Drain the fluid from the pump by removing all bottom drains.

2) Re-fill the pump cavity with water soluble oil or similar solution.

3) Rotate the pump by hand to splash fluid on all internal parts.

4) You <u>must</u> rotate the pump by hand once a week.

Intervac does not accept any responsibility for pumps which have seized while in storage.

- WARNING -

After storage procedure has been followed, the pump must be drained of storage fluid before starting.

8/04/92

RECOMMENDED SPARE PARTS LISTS

We are pleased that you have chosen Intervac to meet your vacuum system requirements.

We support our equipment with a nationwide network of representatives and large inventory of parts in our factory.

We recommend a PM program be set up for your Intervac vacuum system. The recommended procedures are detailed in the parts and service manual.

We would recommend your purchasing some spare parts to minimize down time and help you keep up your preventative maintenance program.

SYSTEM MODEL NUMBER: PSW 1000/1-1FR SERIAL NO: 92052544

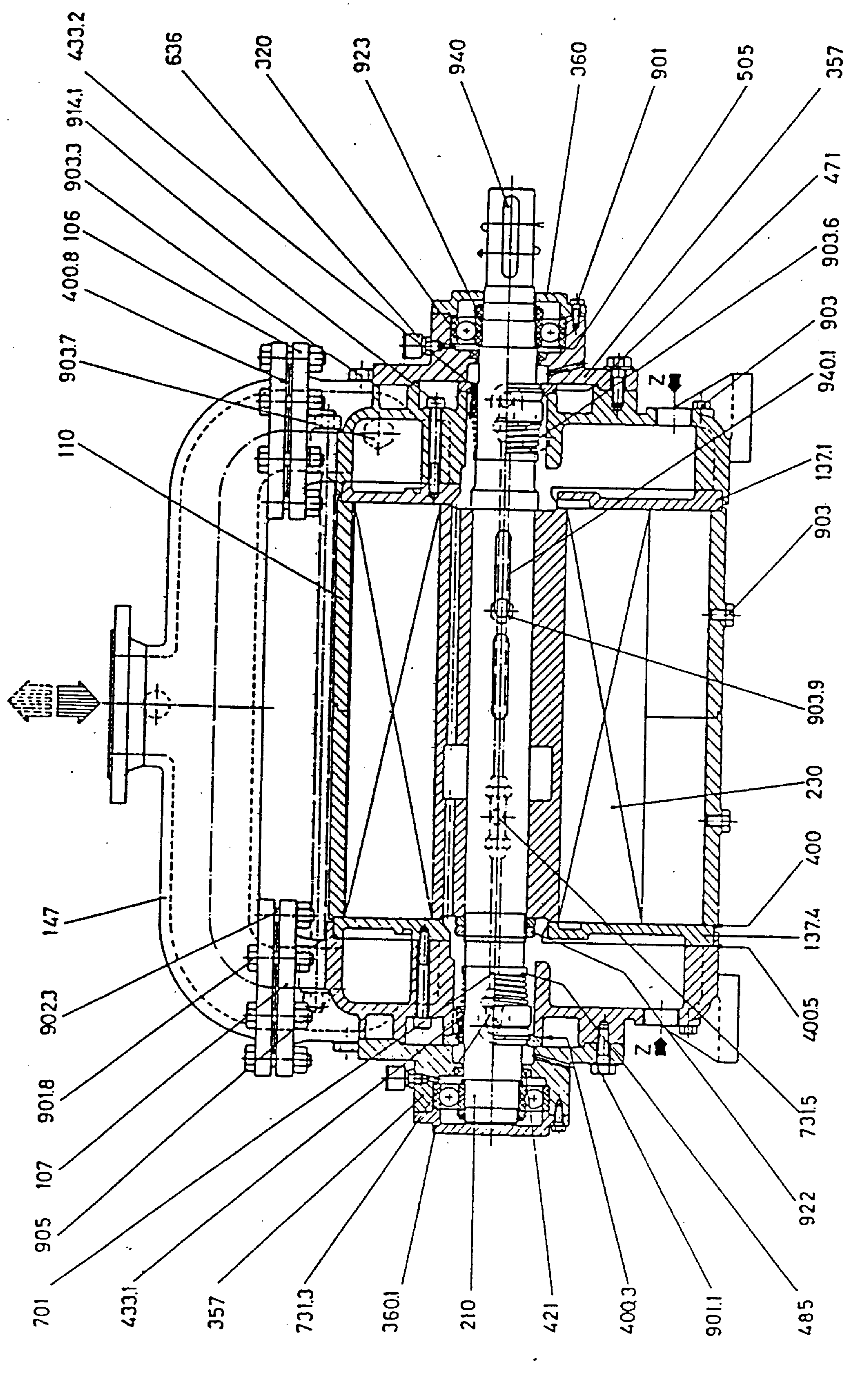
QTY	PART NUMBER	DESCRIPTION	UNIT COST
1	00021266-288	COUPING,HUB, 12S @ 2-7/8"	$ 211.60
1	00021266-060	COUPING,HUB, 12S @ 60mm BORE	325.46
1	00022210-012	ELEMENT,COUPING 12H HYTREL	611.50
1	00045020-000	GAUGE,TEMP. 20/240 F	49.68
1	00056018-000	VALVE,CHECK 5" STD/BUNA	267.30
1	00053112-000	GAUGE,VACUUM 30"Hg FF	39.15
1	00058102-012	SIGHT GAUGE 12" PROT AL/BUNA	75.60
1	00053114-000	GAUGE,COMPOUND 30 X 30 FF	39.15

PARTS FOR VACUUM PUMP MODEL NO: PLM 73/5C-F SERIAL NO:E 8688

2	950075SAC915	MECH. SEAL (D.E.+N.D.E.)	480.60
1	961006314000	BALL BEARING	239.03
1	963NU0314000	ROLLER BEARING	334.69
2	942075100603	LIP SEAL	9.39
1	GPGGUA0005GH	GASKET SET	94.11

PLEASE NOTE: PRICES ARE SUBJECT TO CHANGE WITHOUT NOTICE!

INTERVAC
125 RAWSON ROAD
VICTOR, NY 14564
(716) 924-7080



VACUUM PUMP ASSEMBLY
MODEL PLM 70/C

TRAVAINI PUMPS U.S.A., INC.

MARCH 1992

PARTS PRICE LIST
PUMP MODEL: PLM 73/5C/F

ITEM NO.	QTY	DESCRIPTION		PART NUMBER	PRICE EA.
106.G	1	SUCTION COVER ASBLY.		COR 090 A00 001	1421.42
107.G	1	DISCHARGE COVER ASBLY.		COR 090 B01 001	1242.33
110	1	IMPELLER HOUS.(150mm)		307 08 101 001	1063.27
110.G	1	IMPELLER HOUS.(80mm)		DIT 081 101 001	1066.03
147	2	MANIFOLD		307 381 100 001	1077.23
210.G	1	SHAFT ASSEMBLY		ALB B89 003 040	1709.61
230	1	IMPELLER	+	307 15 100 002	2355.29
320	1	BALL BEARING	+	961 006 314 000	239.03
322	1	ROLLER BEARING	+	963 NUO 314 000	334.69
357	2	BEARING HOUSING		062 16 200 001	559.59
360	1	BEARING COVER (DE)		001 31 100 001	89.55
360.1	1	BEARING COVER (NDE)		001 30 100 001	89.55
400.G	1	GASKET SET		GPG GUA 000 5GH	94.11
421	2	LIP SEAL		942 075 100 603	9.39
433	2	MECH.SEAL (DE&NDE)	*	950 075 SAC 915	480.60
536	2	GREASE FITTING		940 110 000 075	1.92
905	7	TIEBOLT		914 018 650 034	16.58
[illegible]	2	IMPELLER NUT		920 080 220 075	28.73
[illegible]3	2	BEARING NUT		920 070 020 075	28.18
[illegible]10	1	SHAFT KEY (CPLG)		930 080 181 044	39.04
940.1	2	SHAFT KEY (IMPELLER)		930 100 181 044	48.44

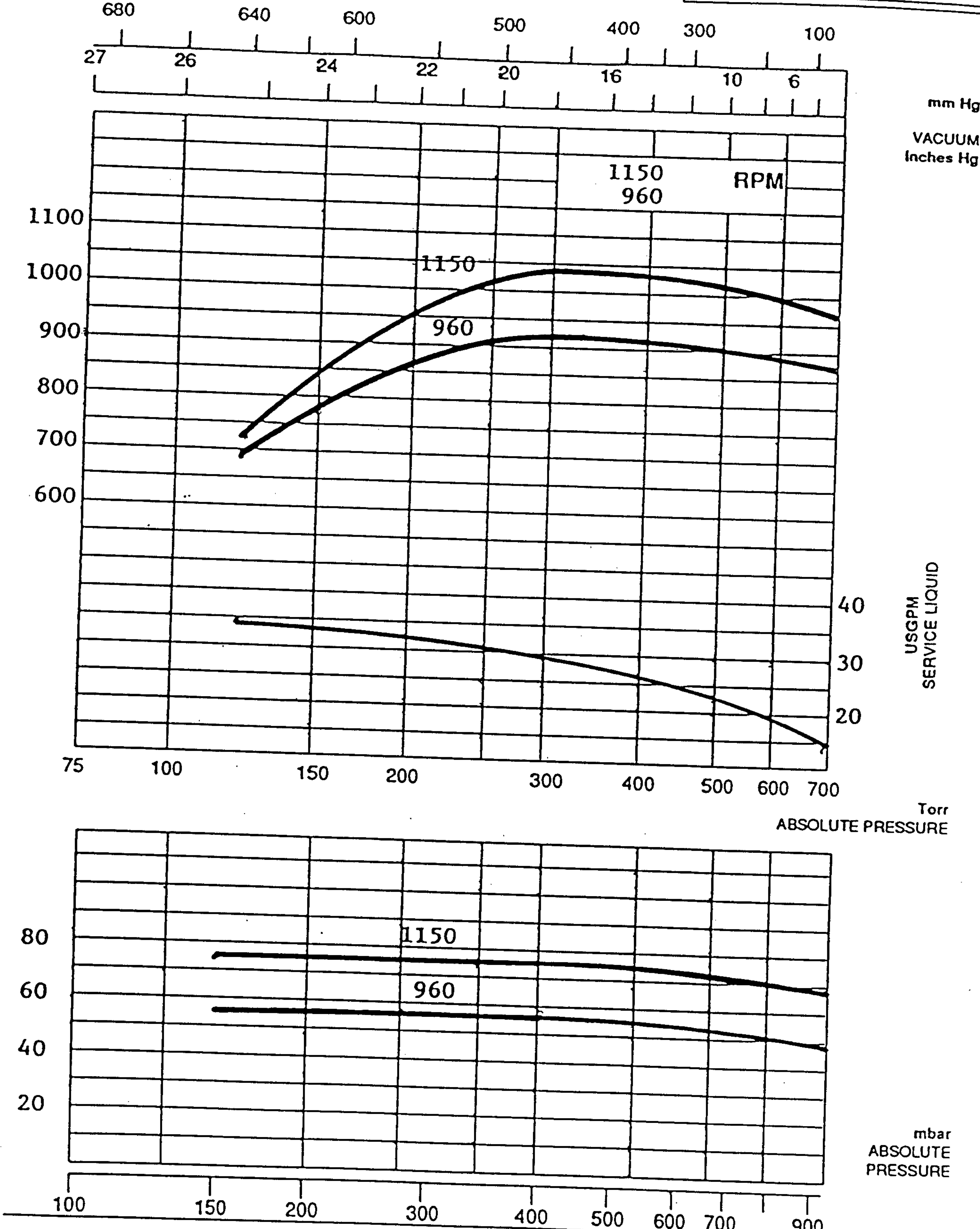
* WHEN ORDERING MECHANICAL SEALS ALWAYS SUPPLY PUMP SERIAL NUMBER TO INSURE CORRECT SEALS ARE SUPPLIED.

ABOVE PRICES SUBJECT TO CHANGE WITHOUT NOTICE.

DATA BASED ON:

Suction dry air	:	70 deg. F
Discharge Pressure	:	29.92" Hg - 760 Torr
Sealing Liquid	:	Water @ 60 deg. F
Tolerance	:	10%

PERFORMANCE DATA
LIQUID RING VACUUM PUMP
PUMP MODEL:
PLM 73



INTERVAC
System Specification Specialists

DATE: OCTOBER 1990

PAGE NO.

Highland TANK & MFG. CO.

st-P3 TANKS • FUEL STORAGE TANKS 275 TO 50,000 GAL. • SPECIAL FABRICATION
ASME PRESSURE VESSELS • STAINLESS STEEL TANKS • OIL-WATER SEPARATORS

OPERATION AND MAINTENANCE INSTRUCTIONS

I. OPERATION INSTRUCTIONS

OIL WATER SEPARATOR

The Highland Tank & Mfg. Co. Oil Water Separator is designed specifically for the separation of multi-phase liquids and solids from petroleum and industrial wastewater. The Highland unit receives, directly from the wastewater drains, various kinds of oil, gasolines, grease and other volatile liquid wastes along with oily sludge; they retain this harmful waste matter and prevent its entry into the drainage system.

The oil water separator should be filled with water at all times for proper operation.

Wastewater enters the top of the tank through the inlet pipe and is directed over the velocity head diffusion baffle, a heavy metal plate, inclined downwardly at a 45 degree angle.

The velocity head diffusion baffle is intended to serve four basic functions:

1. To dissipate the velocity head, thereby improving the overall hydraulic characteristics of the separator.
2. To direct the flow downwardly and outwardly to provide for the most effective use of the separator volume available because the length of the separation chamber begins at the inlet head of the vessel.
3. To reduce flow turbulence and to distribute the flow evenly over the separators cross-sectional area.
4. To isolate the inlet turbulence from the rest of the separator.

Influent suspended solids settle and are collected behind the sludge baffle plate mounted on the separator floor. Lighter density oil droplets and concentrated oil slugs rise immediately to the surface of the separator.

REPLY TO: RT. 30 EAST, BOX 338 • STOYSTOWN, PA 15563 • PH. 814-893-5701 • FAX 814-893-6126

The remaining oily water mixture then passes through the inclined arrangement of parallel corrugated plates.

The corrugated parallel plate separator within the unit improves the efficiency of separation by enlarging the effective separation surface area through the use of multiple parallel corrugated plates.

The Highland Separator utilizes an inclined arrangement of corrugated plates, stacked upward at a 22.5 degree angle, spaced every 3" apart, to prevent fouling by debris and gummy solids. Under laminar flow conditions, buoyancy forces cause oil droplets to rise and coalesce into "sheets" of oil on the underside of each of the plates, creep up the surfaces and finally break loose at the top in the form of large globules that rapidly rise through the separating chamber to the surface. In operation, the maximum distance that an oil particle has to rise for effective removal is the 3" between the plates instead of a few feet, as in standard separators.

The free floating oils and greasy solids accumulate until they are automatically or manually removed from the separator. Purified water is continuously discharge by gravity displacement.

<u>OIL COALESCER: OIL WATER SEPARATORS MODELS HTC</u>

In the Model HTC Oil Water Separators, the wastewater flows from the corrugated plate coalescer to the oil coalescing unit. The purpose of the coalescing unit is to polish the oil water separator effluent before final discharge. This unit is equipped with a polypropylene coalescing material, a ten layer blanket of coarse and fine polypropylene fibers, six inches thick. As the wastewater enters the coalescing media, residual oil particles in the water, down to 20 microns in size, become attached to the oleophilic strands. Once attached, oil globules coalesce; therefore, increasing oil globule size which accelerates the rate of rising oil. The oil globules wick-up the strands and when sufficiently large, break free and rise to the surface of the oil water separator.

ADJUSTABLE OIL SKIMMER

The oil water separator is equipped with an oil skimmer that can be manually adjusted to drain off precisely the amount of oil desired.

The rotary pipe oil skimmer is designed to remove high volumes of skimmed product in large volume oil water separators. The adjustable tube oil skimmer is designed to remove low volumes of skimmed product in low volume oil water separators.

Both skimmers can be manually adjusted to drain off precisely the amount of oil desired. As the product spills into the skimmer it flows by gravity out of the skim pipe through the wall of the separator and into a waste oil storage tank for accumulation and subsequent removal. Periodic checks of the product level in the separator are required.

To set the skimmer for automatic skimming, the skim edge must be set slightly above (about 1/2") the maximum water level when no product is in the oil water separator and the separator is flowing. This setting will assure no water will be skimmed off into the waste oil storage tank.

In operation, during less than maximum flow conditions through the separator, a thick product level will accumulate before skimming takes place because most oil layers drift approximately 80% below and 20% above the original water line. Most of the oil will be removed during maximum flow conditions through the separator.

WATER REMOVAL SYSTEM

The oil water separator is equipped with water level controls to start and stop a water pump at predetermined levels in the integral water sump.

When in operation, water is discharged from oil water separator by gravity into the integral water sump. Water accumulates in the water sump until a predetermined level is reached, at which time a multi-station liquid level control is activated for water pump-on and pump-off. The level control is a magnetic float switch type for liquid level detection. The water removal pump is a vertical centrifugal motor pump with a capacity equal to that of the oil water separator.

The liquid level control floats lie at a set position in the water sump. During wastewater processing, purified water is discharged from the oil water separator into the integral water sump. Waste accumulates within the water sump. Once the water level reaches a high point, the upper liquid level sensor is activated and pump-on is initiated.

When water is pumped out, the sump level drops. When the sump level reaches a low point, one inch above the pump suction, the lower liquid level sensor is activated and pump-off is initiated. The multi-station liquid level control is reset when the water sump is refilled with water.

II. MAINTENANCE INSTRUCTIONS

1. The maintenance of a Highland Gravity Oil Water Separator requires:

   A. Periodic inspection to check for build up of sand, trash, sludge and oil.

   B. Inspection immediately after a heavy rainfall to check for signs of ineffective operation and to determine the presence of oil in the discharge. If contaminants are escaping close the valve on the inlet line immediately and determine what type of maintenance the system may require to return it to effective working order.

2. A possible maintenance procedure for each chamber could include:

   A. Preseparator Chamber: Check to insure the level of sand, dirt, or debris has accumulated to a point no higher than about a foot from the bottom of the tank with a wooden gauge stick. If solids have accumulated to a 12" depth, remove the accumulated material with a suction hose or a vacuum or portable sludge pump. It is recommended that at least once a year, the oil water separator sediment chamber be cleaned. Pump out all fluid from the oil water separator. Direct a high pressure hose downward to loosen up any caked oily solids. Remove the slurry with a suction hose or a vacuum or portable sludge pump.

B. Separator Chamber: Since the compartment separates the oil and grease from the water, check to insure the level of oil and grease has accumulated to a point no lower than the radius of the separator (about 50% of the separator volume). Remove the accumulated oil with a suction hose or a vacuum or portable oil pump. Clean the compartment as it is needed.

C. Coalescer: Since the polypropylene coalescer will remove some suspended solids along with the small oil droplets in the wastewater, periodic cleaning is required. The coalescer can be easily cleaned by removing it from the oil water separator and simply hosing it down upstream of the separator drains in order to wash off any debris or gummy deposits that have accumulated on the fibers. It is

recommended that this cleaning procedure be followed after heavy rainfalls or oil spills. The coalescer can be easily removed reinserted through the access manhole in the oil water separator top.

3. Over a period of time, the sediment, oil and grease will build up on the walls of the separator. Dirt and heavy oil may build up on the parallel plates and the build-up will reduce the unit's efficiency. Also, the skimmer mechanism becomes gummy. This causes partial clogging of the mechanism and the formation of a continual oil slick of increasing depth.

It is recommended that the oil water separator be cleaned at least once a year. Annual cleaning consists of removing the oil build-up on surfaces of the oil water separator walls and coalescer plates with steam or high pressure wash. Pumpout all fluid from the oil water separator tank. Direct the steam or high pressure wash against the oil water separator walls and coalescer plates. A wand extension nozzle may be required reach into and around the oil water separator tank. Rotate the nozzle sufficiently often so that all areas are reached with the spray.

If contaminants are present, or if detergents are used in the cleaning process, always be sure to pump out before reactivating the system and reopening the valve on the influent line. Since oil water separator designs will vary with sites, it is essential to adhere strictly to the manufacturer's instructions for cleaning and maintenance.

4. Record Keeping: Keep a log of inspection and maintenance work and have it available for ready reference.

Highland Oil Water Separator, although of modern design, cannot be expected to perform well without receiving necessary attention.

1. The amount of debris such as sand, gravel, dirt, leaves, wood, rags, etc. permitted to enter the separator must be minimized for maximum effectiveness. Catch basins and drains installed ahead of the separator should be inspected and cleaned on a regular basis.

2. Waste oil such as automobile and truck crank case oil should not be intentionally drained into the separator. Waste oil should be dumped into the waste slop tank for proper disposal.

3. Highland Separators should be maintained as free of accumulated oil and sediment as possible. A simple and effective means is required to remove these accumulated deposits. Access for truck pumpers for sludge and oil removal is mandatory.

4. It is imperative that detergents and solvents be excluded from the separator system. The gravity separator will not remove chemical emulsions or dissolved hydrocarbons and their presence retards the recovery of oil that would otherwise be separated. Waste water containing a high dissolved solids concentration, such as untreated sanitary sewage, must be excluded due to its emulsifying tendency.

5. The separator inlet and outlet piping must be sloped from 1/8" to 1/16" per foot to maintain proper gravity flow. Inlet piping should be installed straight and true with few turns to limit turbulence.

6. The absence of gravity flow to the separator will make it necessary to pump the waste waters. When elevation or grades at the facility fail to allow for gravity flow through the oil water separator, pumping must be restricted to the clean water, effluent-discharge end of the separator. If pumping goes on ahead of the separator, it will tend to mix the oily water and increase the emulsified and dissolved

oil content, possibly to the point that the oil and water separation fails. If a pump is installed upstream of the separator, it must be a positive displacement pump, at minimum gpm, and installed as far upstream as possible to reduce the extent of mixing.

7. Oils with a specific gravity greater than 0.95 require special treatment.

8. Separators should be provided with a means of shutting off the in-flow and out-flow for the purposes of cleaning and emergency situations.

9. For economies of separator design, water run-off from essentially oil-free areas is routed around the separator. Otherwise, the separator requirement becomes too large.

10. The separator system should be kept from freezing at all times. Two of the most available methods available to achieve this are as follows:

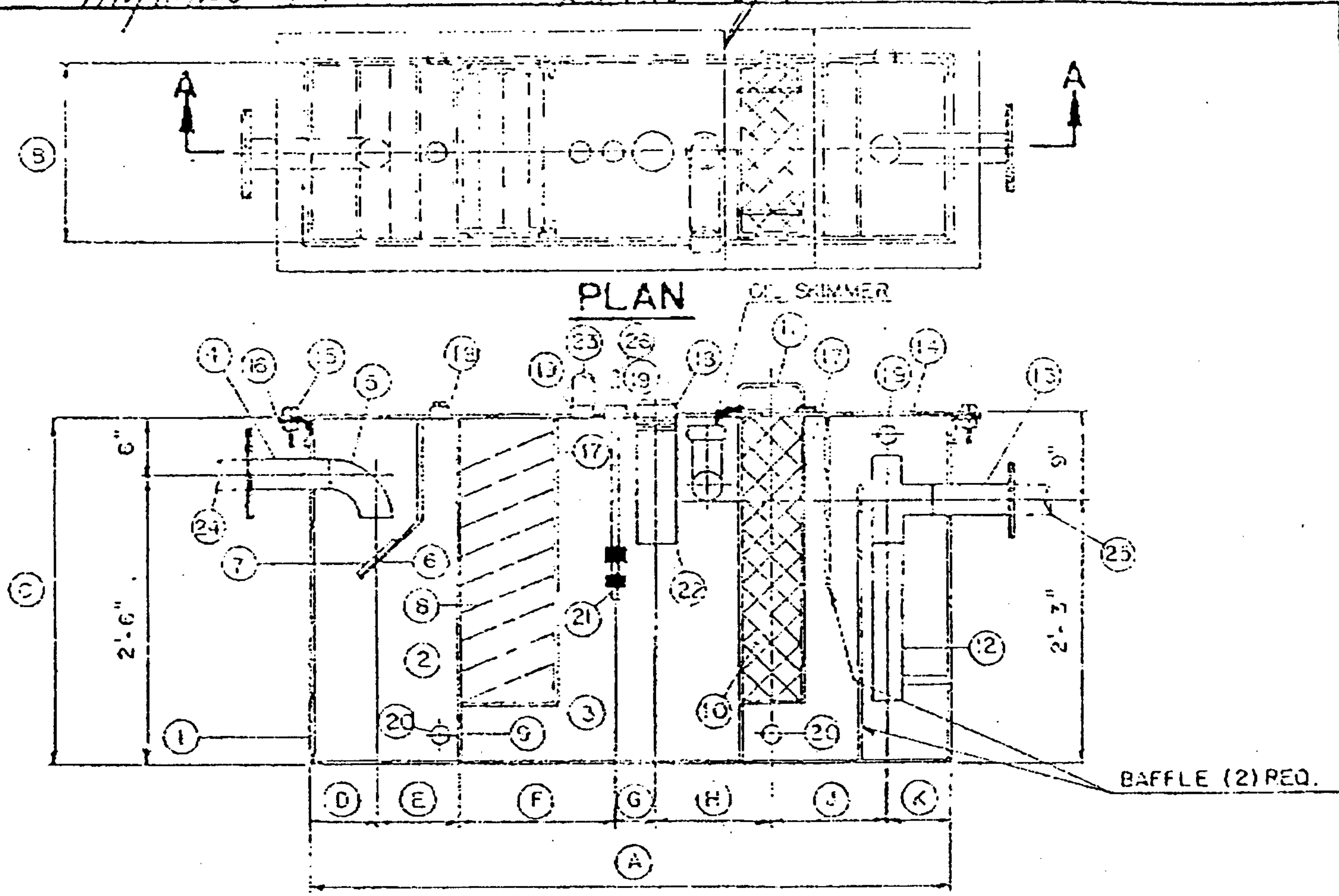
A. The separator may be located at an elevation so that the top of the liquid is below the frost line.

B. If the frost line is too deep to allow for economical location beneath, insulation and/or the inclusion of heating devices in the separator may be applied.

11. To summarize briefly some of the factors that adversely affect separator performance:

A. Excessive turbulence.
B. Pumping into the separator.
C. Too high a feed rate.
D. Detergent or surfactants.
E. Inefficient oil removal.
F. Sludge build-up on the bottom.

Highland Tank Co. – EnviroReps – Denver Co.



STANDARD EQUIPMENT

1. OIL-WATER SEPARATOR
2. SEDIMENT CHAMBER
3. OIL-WATER SEPARATION CHAMBER
4. FLANGED INLET
5. INLET NOZZLE
6. VELOCITY HEAD DIFFUSION BAFFLE
7. WEAR PLATE
8. REMOVABLE PARALLEL CORRUGATED PL
9. SLUDGE BAFFLE
10. COALESCER PACK
11. COALESCER COVER PLATE W/ HANDLES
12. OUTLET DOWN COMER
13. FLANGED OUTLET
14. REMOVABLE COVER
15. NON-CORROSIVE BOLTS
16. NEOPRENE GASKET
17. 6" STEEL CHANNEL GUIDE
18. 3" NPT CLEAN-OUT WITH PLUG
19. 2" NPT
20. 2" NPT DRAIN WITH PLUG

OPTIONAL EQUIPMENT

21. LEVEL SENSOR
22. OIL PUMP-OUT PIPE

CONTRACTOR FURNISHED EQUIPMENT

23. 2" VENT PIPING
24. INLET PIPING AND FITTINGS
25. OUTLET PIPING AND FITTINGS
26. 1" CONDUIT, FITTINGS & WIRING

SCHEDULE OF STANDARD SIZE OIL-WATER SEPARATORS

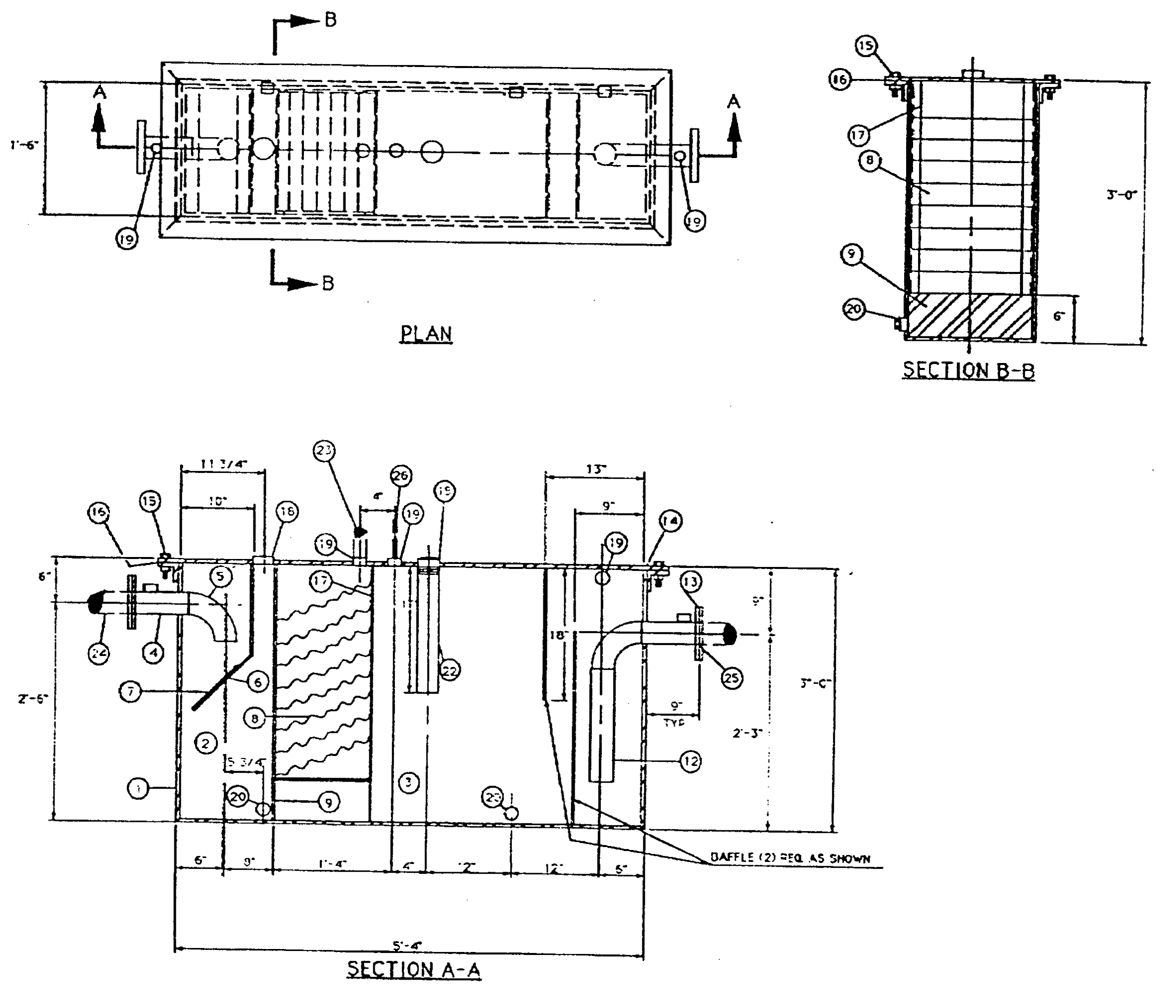
MODEL	G.P.M.	A	B	C	D	E	F	G	H	J	K
HTLC-30	30	5'-4"	1'-6"	3'-0"	6"	6"	1'-4"	4"	12"	12"	6"
HTLC-60	60	7'-6"	1'-6"	3'-0"	9"	2'-9"	1'-3"	6"	9"	1'-0"	6"
HTLC-90	90	9'-0"	1'-6"	3'-0"	9"	3'-6"	2'-0"	6"	9"	1'-0"	6"

HIGHLAND TANK & MANUFACTURING CO.
OIL-WATER SEPARATOR-HTLC
PATENT NO. 4,722,800

CUSTOMER

NONE | 8-12-92 | Represented by | E-589

EnviroReps, Inc.
2921 S. Downing
[redacted] 10 [redacted] (303) 761-



STANDARD EQUIPMENT

1. OIL WATER SEPERATOR
2. SEDIMENT CHAMBER
3. OIL WATER SEPERATION CHAMBER
4. FLANGED INLET 3" Ø
5. INLET NOZZLE
6. VELOCITY HEAD DIFFUSION BAFFLE
7. WEAR PLATE
8. REMOVABLE PARALLEL CORRUGATED PLATES
9. SLUDGE BAFFLE

12. OUTLET DOWN COMER
13. FLANGED OUTLET 3" Ø
14. REMOVABLE COVER
15. NON-CORROSIVE BOLTS
16. NEOPRENE GASKET
17. 6" STEEL CHANNEL GUIDE
18. 3" NPT CLEAN-OUT WITH PLUG
19. 2" NPT
20. 2" NPT DRAIN WITH PLUG

22. OIL PUMP-OUT PIPE

CONTRACTOR FURNISHED EQUIP.

23. 2" VENT PIPING
24. INLET PIPING AND FITTINGS
25. OUTLET PIPING AND FITTINGS
26. 1" CONDUIT, FITTINGS AND WIRING

GENERAL NOTES

5. TANK CONSTRUCTED OF [illegible] MILD CARBON STEEL
7. INTERIOR COATING: NONE
8. EXTERIOR COATING: [illegible]

NO.	DATE	DESCRIPTION

REVISIONS

HIGHLAND TANK & MFG. CO.
STOYSTOWN, PA.

OIL WATER SEPERATOR HTC 30
PATENT NO. [illegible]
COPYRIGHT © 1986 [illegible]

CUSTOMER: [illegible]

Dieterich Standard
A DOVER Industries Company

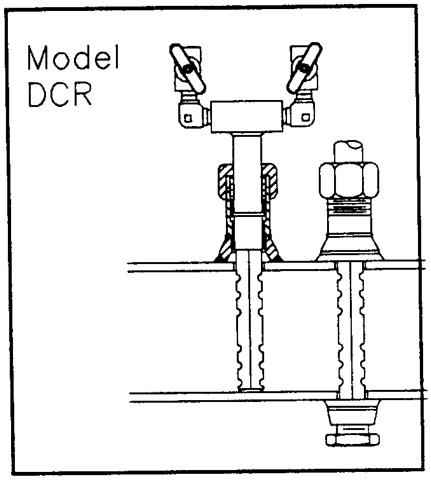
Flow Measurement Systems

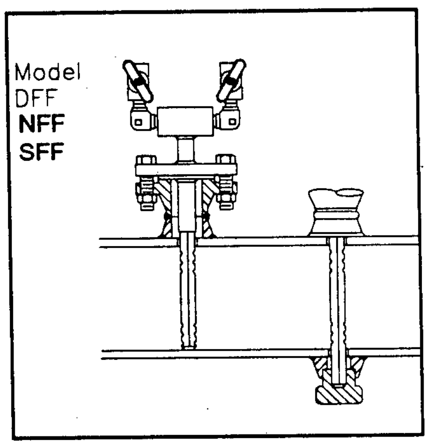
Diamond II Annubar

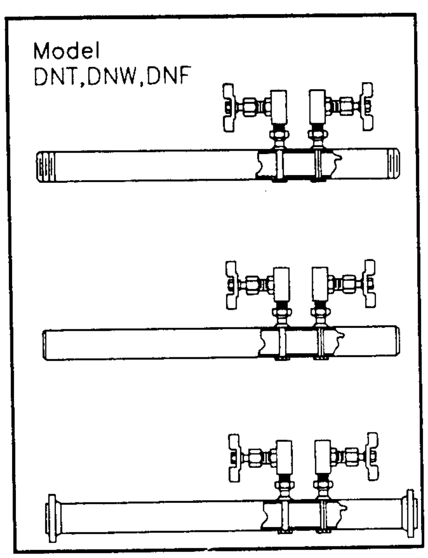
Installation, Operating & Maintenance Manual
Liquid, Gas Service Horizontal & Vertical Pipes

Models:DCR-15/16, DCR-25/26, DCR-35/36, DCR-45/46
DFF-15/16, DFF-25/26, DFF-35/36, DFF-45/46
DFF-15/16 Pak-Lok, DFF-25/26 Pak-Lok
DFF-35/36 Pak-Lok, DFF-45/46 Pak-Lok
DNT-10, DNW-10, DNF-10
NFF-16, NFF-26, NFF-45/46
SFF-43/44

Contents







1. Receiving & inspection

Upon receipt of shipment, check the packing list against material received and the purchase order. All items are tagged with model number, serial number and customer tag number. Any damages should be reported to the carrier.

2. Annubar description

The Annubar is a primary flow sensor designed to produce a differential pressure that is proportional to flow.

The Annubar accurately measures liquid, gas or air flows in pipes or stacks.

The Annubar is available in many different models, each designed for a variety of flow applications providing high, long-term accuracy, low permanent pressure loss, low installed cost and low operating cost resulting in energy savings. The Annubar models include: flanged, Pak-Lok, pipe sections and Flo-Taps. The models are available in line sizes from 1/2" to over 30 feet in diameter.

3. Operating limitations

3.1 Structural limitations

The maximum allowable temperature, pressure, differential pressure is printed on the metal tag attached to the Annubar. Operation in excess of any maximum flow parameter could result in severe damage to the flow sensor and surrounding system components.

3.2 Functional limitations

For the Annubar to produce accurate, repeatable flow measurement, the following must be considered:

1. For air and gas measurement, the differential pressure should be above 0.2" water column at minimum flow.

4. Location

2. For Liquid measurement, the differential pressure should be above 1" water column at minimum flow.

3. The Annubar will not accurately measure two-phase flow or steam below the saturation temperature.

4. For steam measurement, the differential pressure should be above 2" water (HL) or 5.0" water (VL) at minimum flow.

Location

Correct location of the Annubar in the piping branch is important since flow disturbances can affect the accuracy of measurement.

4.1 Straight run requirements

Use chart A to determine proper installation location.

Notes:

If longer lengths of straight run are available, position the Annubar where 80% of the run is upstream of the Annubar and 20% is downstream.

Information applies only to circular pipes.

Straightening vanes may be used to reduce the required straight run length.

Annubar will provide a repeatable signal in straight runs less than shown. Consult your local Dieterich Standard representative or Dieterich Standard.

Figure 6, Chart A, applies to gate, globe, plug, and other throttling valves that are partially opened. If a "through-type" valve is to be open, use values shown in Chart A Figure 5. If the Annubar should be located downstream of control valve see Figure 6 for straight run requirements.

Figure 1 - Persmissable misalignment

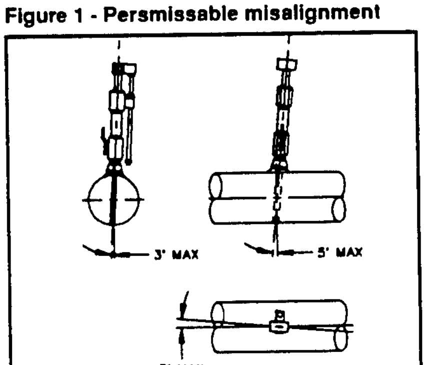
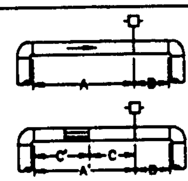
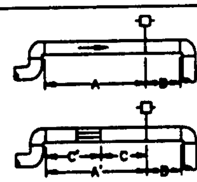
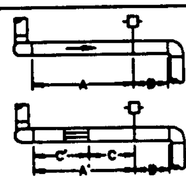
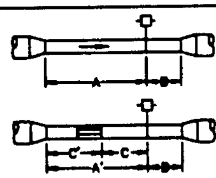
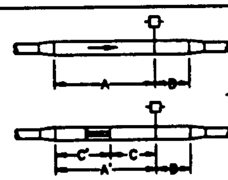
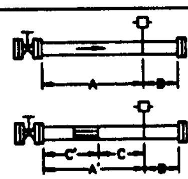


Chart A - Straight run requirements

MINIMUM DIAMETERS OF STRAIGHT PIPE [1]	UPSTREAM DIMENSION					DOWNSTREAM DIMENSION
	WITHOUT STRAIGHTENING VANES		WITH STRAIGHTENING VANES			
	IN PLANE A	OUT OF PLANE A	A'	C	C'	B
Fig. 1 	7	9				3
			6	3	3	
Fig. 2 	9	14				3
			8	4	4	
Fig. 3 	19	24				4
			9	4	5	
Fig. 4 	8	8				3
			8	4	4	
Fig. 5 	8	8				3
			8	4	4	
Fig. 6 	24	24				4
			9	4	5	

4.2 Alignment limits

The permissable misalignment is illustrated in Figure 1. Installation outside of these limits will cause error in flow measurement.

4.3 Pulsation & vibration

Location of the Annubar in pulsating flow will cause a noisy signal. Vibration can also distort the output signal and compromise the structural limits of the Annubar. Mount the Annubar in a secure run of pipe as far as possible from pulsation sources such as check valves, reciprocating compressors or pumps and control valves

4.4 DP transmitter location

Before selecting an Annubar location, the DP transmitter location must be considered.

Liquid applications - Locate below the level of the Annubar instrument connections.

Air and gas applications - Locate above the level of the Annubar instrument connections.

Connecting lines should be as short as possible, but of sufficient lenght to cool the process fluid to the temperature limits of the transmitter. The transmitter and connecting lines should be mounted in a stable, vibration-free environment.

5. Annubar orientation

Annubar orientation

To ensure accurate flow sensing, proper orientation of the Annubar is important. Annubar instrument head connections differ on horizontal and vertical pipes. Consult your specification code number to confirm the proper pipe orientation for your Annubar.

<u>Head code number</u>

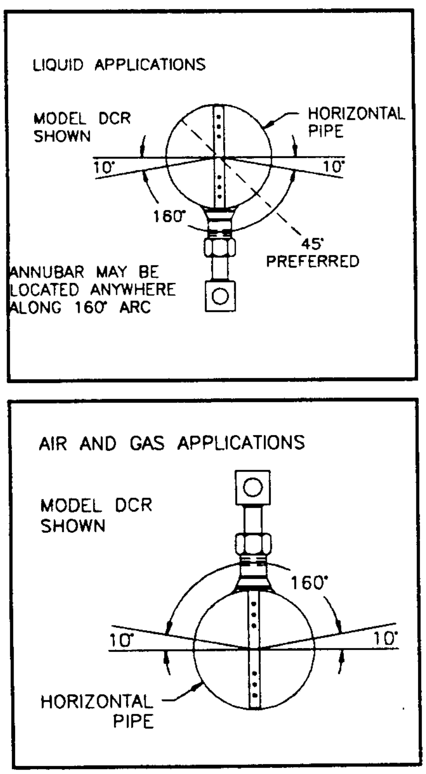
HA1, HA2, HPF, NA2 - horizontal pipe
HV1, HV2 , NV2- Vertical pipe

5.1 Horizontal pipes

Liquid applications - The Annubar is to be located on the bottom half of the pipe at least 10° below the horizontal line (45° preferred). See Figure 2.

Air and gas applications - The Annubar is to be located on the upper half of the pipe at least 10° above the horizontal line. See figure 2.

Figure 2 Annubar orientation
Models: DCR, DFF, NFF, SFF, DNT, DNW and DNF horizontal pipes

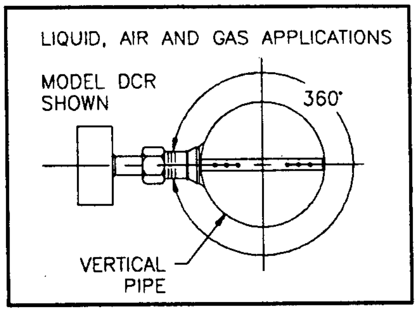


5.2 Vertical pipes

Liquid, air and gas applications - The Annubar can be installed in any position around the circumference of the pipe. See figure 3.

6. Annubar installation

Figure 3 Annubar orientation
Models : DCR ,DFF, NFF & SFF
Vertical pipes



Annubar installation

6.1 Installation instructions

Refer to the following publications for specific Annubar model installation instructions (Chart B).

Chart B Installation instructions

Annubar model	Literature Number
DCR-15/16, 25/26, 35/36	DS-1246
DCR-15/16, 25/26, 35/36 Steam horizontal lines (HL)	DS-1247
DCR-15/16, 25/26, 35/36 Steam vertical lines (VL)	DS-1248
DCR-45/46	DS-1249
DCR-45/46 Steam (HL)	DS-1250
DCR-45/46 Steam (VL)	DS-1251
DFF-15/16, 25/26, 35/36 NFF-16, 26	DS-1298
DFF-45/46, NFF-45/46, SFF43/44	DS-1611
DFF-15/16, 25/26, 35/36 Pak-Lok	DS-1240
DFF-15/16, 25/26, 35/36 Pak-Lok Steam (HL)	DS-1242
DFF-15/16, 25/26, 35/36 Pak-Lok Steam (VL)	DS-1243
DFF-45/46 Pak-Lok	DS-1241
DFF-45/46 Pak-Lok Stm (HL)	DS-1245
DFF-45/46Pak-Lok Stm (VL)	DS-1244
DNT-10, DNW-10, DNF-10	DS-1294
DFF-45/46, SFF-43/44 Stm (VL)	DS-1621
DFF-45/46, SFF-43/44 Stm (HL)	DS-1612

6.2 Valves & fittings

Use only valves and fittings rated for the process line design pressure and temperature.

Use properly rated pipe thread sealant compound when installing valve and fittings.

Verify all connections are tight and instrument valves are fully closed.

Install valves and fittings per the applicable drawings. (See Fig 4 & 5.)

Figure 4 Horizontal pipes
Models DNT,DNW & DNF

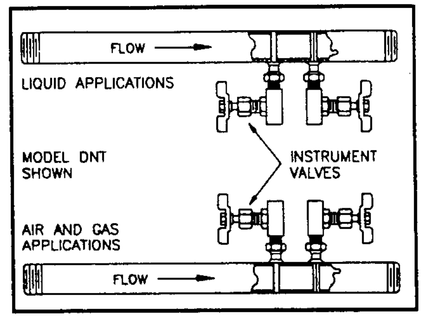


Figure 5 horizontal pipes
Models DCR , DFF, NFF & SFF
Axial instrument head

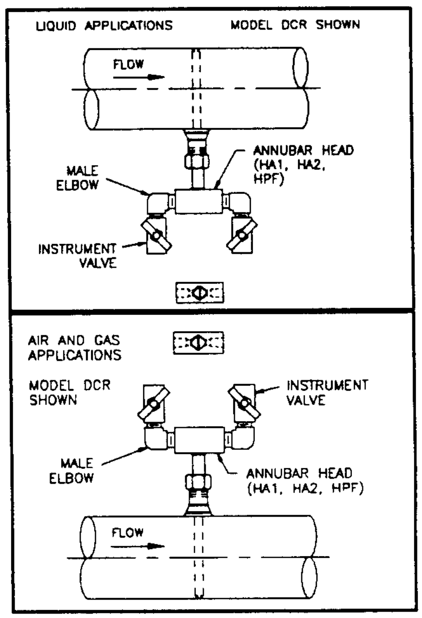
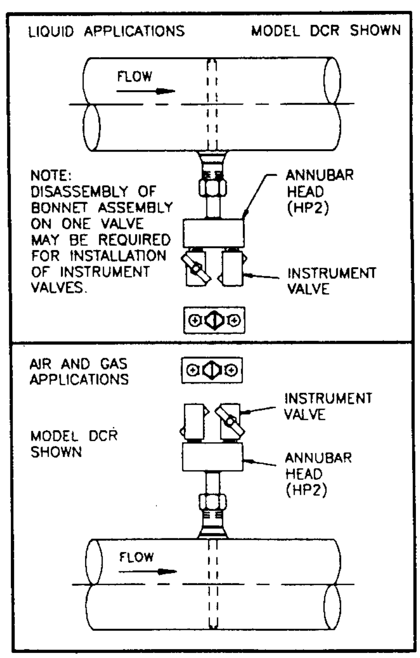
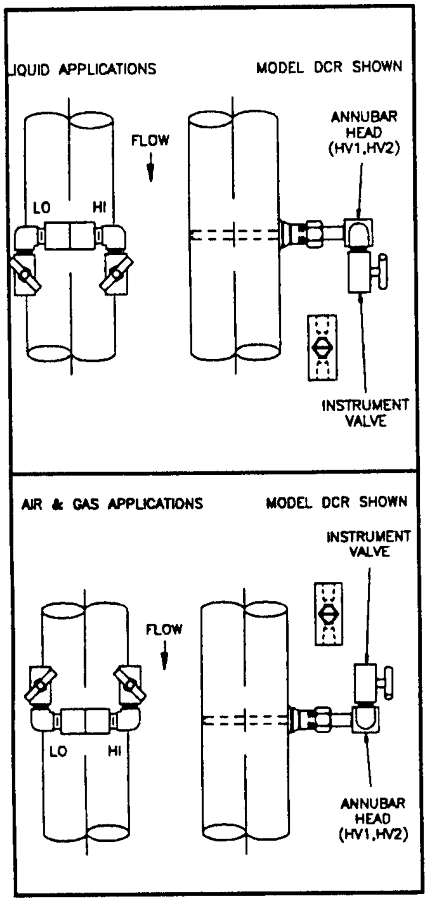


Figure 6 Vertical pipes
Models: DCR , DFF, NFF, SFF



7. Secondary instrumentation descriptions

Figure 7 Vertical pipes
Models: DCR, DFF, NFF & SFF
Axial instrument head



Secondary instrumentation description

7.1 Connecting tubing

The following requirements should be carefully observed.

1. In high temperature applications, the connecting lines should be rated for the service conditions and should be long enough to ensure the temperature at the D.P. transmitter is less than 200°F (93°C). Temperature limitation is for Dieterich Standard 1151 transmitter with silicone filled element and for the Dieterich Standard Pro-Ducer 2000 Series transmitters and meters. The temperature limits may be lower for other transmitters. See transmitter installation instructions for specific temperature limitations. (One foot of stainless steel tubing equals 100°F of cooling.) Outdoor installations may require heat tracing to prevent connecting lines from freezing.

2. Connecting lines must slope at least on inch per foot and must be supported to prevent sagging and vibrations.

3. Connecting lines must have no peaks, dips, or loops. Avoid sharp bends. Bends should have a minimum radius equal to three times the O.D. of the tubing.

4. The connecting lines must be close together to maintain equal temperature. CAUTION: Do not allow nylon or rubber lines to contact hot pipes or other heat sources.

5. Connecting lines must be completely air tight.

6. Run connecting lines in protected areas such as conduit, channels, I-beams or angles, and against walls or ceilings. Protect horizontal runs that are near the floor or under work areas with steel sheeting or kick plates.

7. Periodically check all connections for tightness when vibration and/or thermal cycling are present.

7.2 5-valve manifold

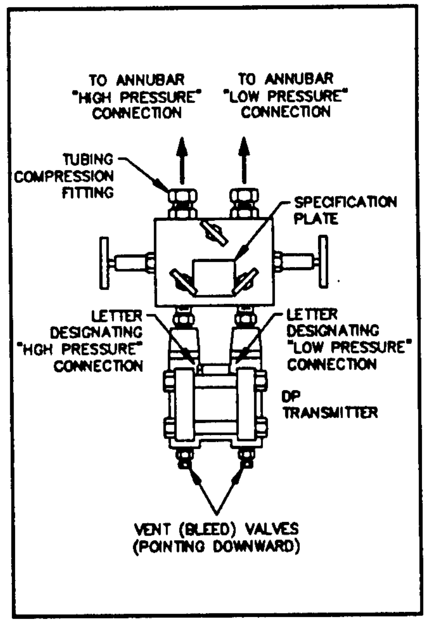
Isolating the process fluid from the transmitter using a manifold is recommended.

CAUTION: If no manifold is to be used, slowly open both Annubar valves during start-up to avoid damaging the D.P. transmitter or other secondary instruments.

A 5-valve manifold is preferred over a 3-valve. The two equalizer valves and vent valve provided with a 5-valve manifold have two advantages (See Figure 6).

Advantages:
1. Certainty of equalizer shut off.
2. Positive indication of equalizer valves needing repair.

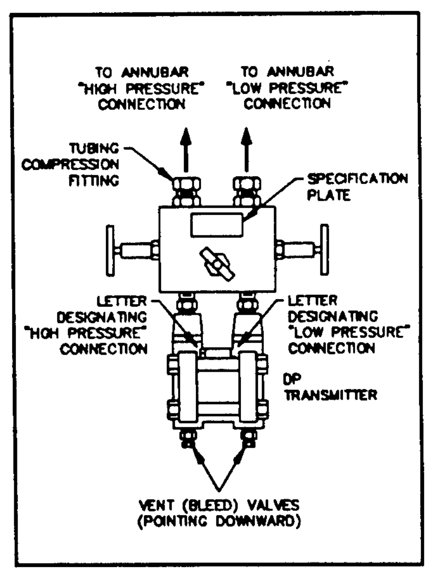
Figure 8 - 5-valve manifold



7.3 3-valve manifold

A 3-valve manifold may be used but at the cost of losing the important advantages stated in section 7.2 (See figure 9).

Figure 9 - 3 valve manifold



7.4 D.P. transmitter

1. The D.P. transmitter should be mounted as follows:

   Liquids - Locate below the level of the Annubar instrument connections.

   Air & Gas - Locate above the level of the Annubar instrument connections.

2. Trace the connecting lines from the Annubar to the transmitter to verify that the high and low pressure connections from the Anuubar connect to the appropriate sides of the transmitter. (The high and low pressure sides of the transmitter are marked "H" and "L".)

3. A D. P. transmitter should be oriented so that the bleed valves are pointing downward. See Figures 8 & 9.

4. Maximum permitted transmitter temperature is 200°F (93°C).

5. Refer to the transmitter installation instructions, DS-4200 for 1151 Series transmitters and the DS-6203, and DS-6253 for the Pro-Ducer Series 2000DX transmitter. Refer to the DS-6200, and DS-6250 for the Pro-Ducer Series 2000RM, 2000TM and 2000CX meters and computing transmitters for wiring, other requirements, and limitation of the transmitters, meters and computing transmitters.

6. Readouts or controls receiving the transmitter's signal may be placed in any convenient location.

7.5 Secondary instrumentation and orientation - liquids

The following diagrams are recommended secondary instrumentation for specific liquid flow applications.

Horizontal pipe, liquids

Figure 10 - Standard orientation
Models: DCR, DFF, NFF & SFF

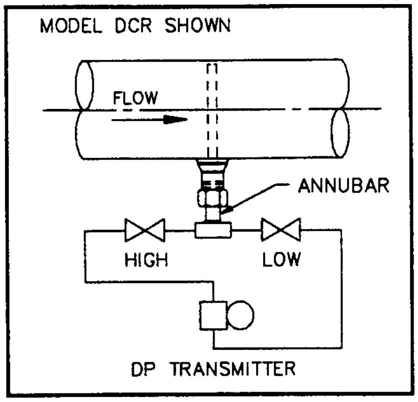
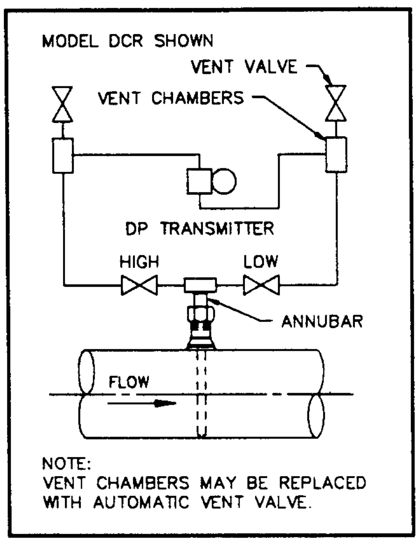
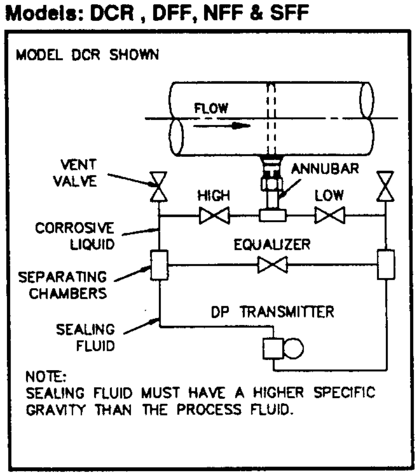


Figure 11- Top of pipe installation
Models: DCR, DFF, NFF & SFF



Note: Sealing fluid must have a higher specific gravity than the process fluid.

Figure 12 - Corrosive applications
Models: DCR , DFF, NFF & SFF



Vertical pipe, liquid

Figure 13 - Standard orientation
Models : DCR, DFF, NFF & SFF

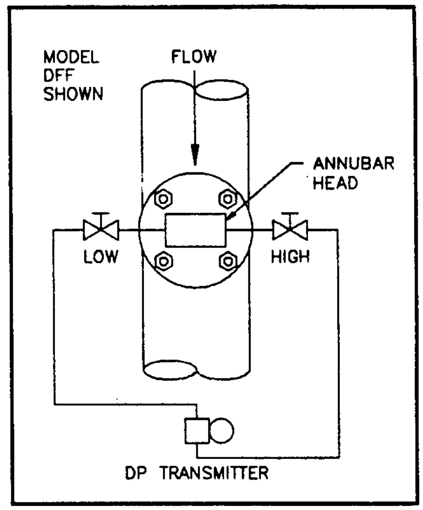
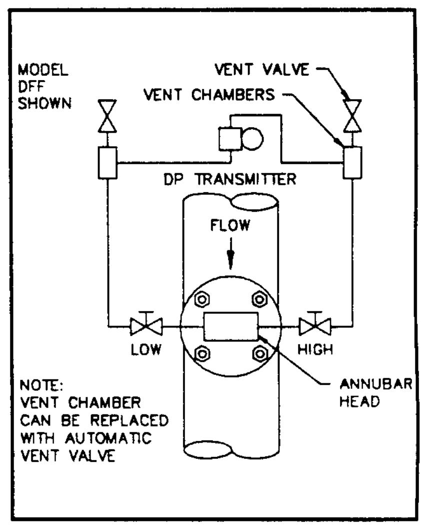


Figure 14 - Transmitter above the Annubar
Models: DCR, DFF, NFF & SFF



8. Start-up procedure

7.6 Secondary instrumentation and orientation - air & gas

The following diagrams are recommended secondary instrumentation orientation for specific gas and air applications.

Horizontal pipe, gases

Figure 15 - Standard orientation
Models: DCR ,DFF, NFF & SFF

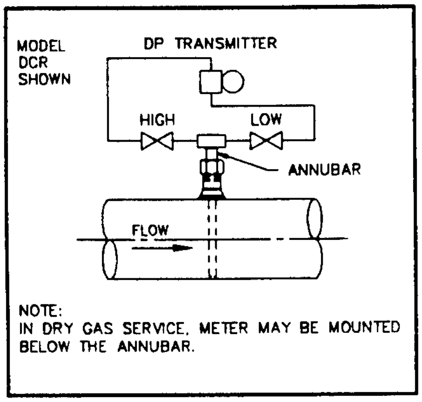
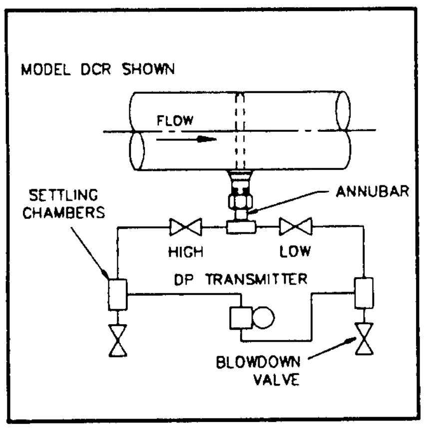
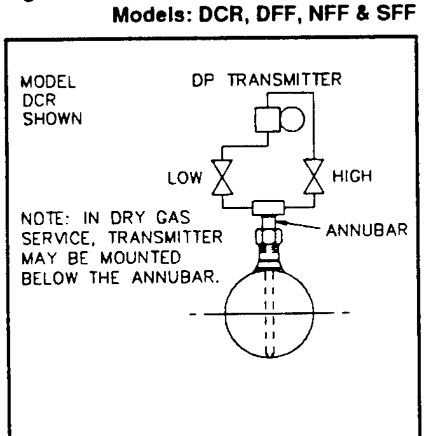


Figure 16 - Wet gas applications
Models: DCR , DFF, NFF & SFF



Vertical pipe, gases

Figure 17- Standard Orientation
Models: DCR, DFF, NFF & SFF



Start-up procedure

8.1 Zero the transmitter models 1151 and 2000DX

Before the D. P. transmitter is exposed to line pressure, check the zero calibration (with no condensate in the instrument lines and the Annubar valves H & L closed). See figures 16 or 17. At this point, the transmitter should be installed with the proper power supply powering the signal loop. With the transmitter oriented so that the vent valves are facing down, measure the current across the "signal" terminals; the reading should be 4mA. If the current is not 4mA, adjust the zero until the transmitter signal reads 4mA. (For Dieterich Standard's model 1151, and Pro-Ducer model 2000DX do NOT touch the range screw as this changes the transmitter calibration.)

8.1.1 Zero the models 2000RM, 2000TM & 2000CX

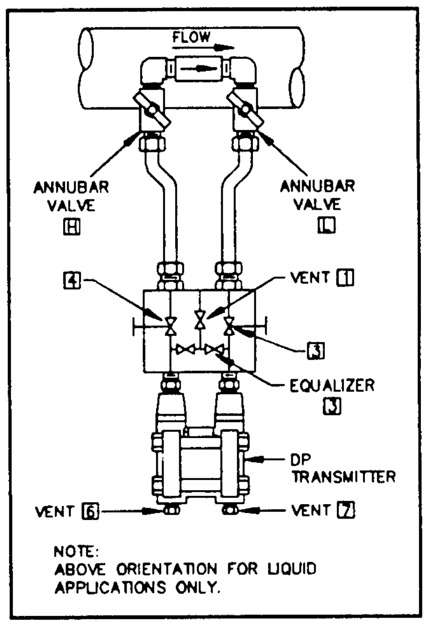
Before the D.P. meter is exposed to line pressure, check the zero calibration (with no condensate in the instrument lines, the equalizer open, and the Annubar valves H & L closed). See figures 16 and 17. At this point, the meter should be installed with the proper power supply powering the signal loop. With the meter oriented so that the vent valves are facing down. Use the keypad to bring the display to the "CALZERO". Press "↓ " to display "SETZERO". With no D.P. applied to the cell, press the "↓ "key to dispaly "CALZERO". The zero is now set.

8.2 5-valve manifold, liquids

Before start-up is attempted, be sure all valves shown are fully closed. See figure 16 for valve identifications while following the procedure given below.

1. With Annubar valves closed (H & L), open valves 2,3,4 and 5. Slowly open valve L, the low pressure instrument connection.
2. Open vent valves 6 & 7 to bleed air out of system.
3. Close vent valves 6 & 7.
4. Slowly open vent valve 1 to bleed out and entrapped air in the manifold. Allow water to run out of the valve until the entrapped air is no longer in the system. Close valve 1.
5. Slowly open valve 7 and allow water to flow out freely. Then close valve 7.
6. Slowly open valve 6 and allow water to flow out freely. Close valve 6.
7. Gently tap transmitter body, valve manifold, and instrument tubing with a small wrench to dislodge any remaining entrapped air.
8. Repeat step 4.
9. Repeat steps 6 and 7.
10. Close equalizer valves 2 and 3.
11. Slowly open Annubar valve H, the high pressure instrument connection.
12. Open valve 1. If there are no leaks between valves 2 and 3 then no leaking at valve 1 should occur. If valve 1 is leaking, valves 2 and 3 are not fully closed or require repair.
13. The system is now fully operational.

Figure 18 - 5-valve manifold indentification



8.3 5-valve manifold, air & gas

Before start-up is attempted, be sure all valves shown are fully closed. See figure 16 for valve identifications while following the procedure given below.

1. With Annubar valves closed (H & L), open valve 2, 3, 4 and 5. Slowly open valve L, the low pressure instrument connection.

2. If wet gas or moisture is in the instrument tubing, open vent valve 6 to allow the condensate to drain. Close valve 6.

3. Repeat step 2 if necessary to vent valve 7 to allow trapped condensate to drain.

4. Close equalizer valves 2 & 3.

5. Slowly open Annubar valve H, the high pressure instrument connection.

6. Open vent valve 1. If there are no leaks between valves 2 and 3, then no leaking at valve 1 should occur. If valve 1 is leaking, valves 2 and/or 3 are not fully closed or require repair.

8.4 3-valve manifold, liquids

Before start up is attempted, be sure all valves shown are fully closed. See figure 17 for valve identifications while following the procedure given below.

1. With Annubar valves H & L closed, open valves 2 & 3 and equalizer valve 1.

2. Slowly open valve L, the low pressure instrument connection.

3. Slowly open vent valves 4 & 5 and allow air to bleed out of the system.

4. Close vent valves 4 & 5.

5. Gently tap transmitter body, valve manifold, and instrument tubing with a small wrench to dislodge any remaining entrapped air.

6. Repeat steps 3 & 4.

7. Close equalizer valve 1.

8. Slowly open Annubar valve H, the high pressure instrument connection.

9. The system is now fully operational.

8.5 3-valve manifold air & gas

Before start-up is attempted, be sure all valves show are fully closed. See figure 17 for valve idenification while following the procedure below:

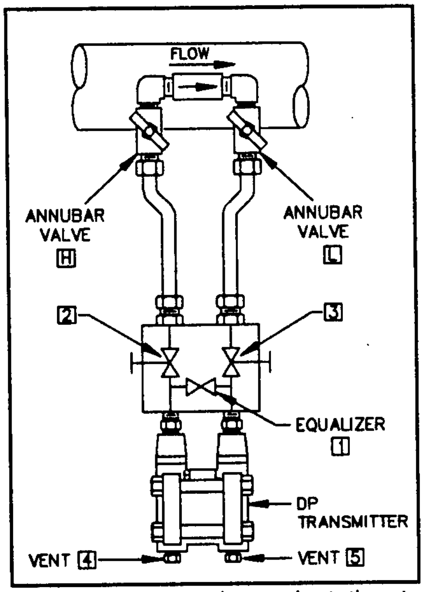
1. With Annubar valves H & L closed, open valves 2 & 3 and equalizer valve 1.

2. Slowly open valve L, the low pressure instrument connection.

3. If wet gas or moisture is in the instrument tubing, open vent valve 4 to allow the condensate to drain. Close valve 4.

4. Repeat step 3 if necessary to vent valve 5 and allow the condensate to drain.

Figure 19 - 3-valve manifold idenification



NOTE: DP transmitter orientation to pipe is correct for liquid applications only.

5. Close equalizer valve 1.

6. Slowly open Annubar valve H, the high pressure instrument connection.

7. The system is now fully operational.

9. Readings & calculations
10. Maintenance

Reading & calculations

The Annubar produces a differential pressure proportional to the square of the fluid velocity. This differential pressure is equated to a flow rate through equations described in the Annubar Flow Handbook. Calculations can be performed using these equations. Precise factory flow calculations are available for individual applications. Where less accuracy is acceptable, an Annubar flow calculator is available and may be used to determine flow rate from the differential pressure signal.

Maintenance

The Annubar is virtually a maintenance free device. however, an annual inspection is recommended. If the sensor needs cleaning, the following procedure can be followed:

1. Remove the Annubar sensor.
CAUTION: To prevent personnel injury when removing Annubar, withdraw sensor, close isolation valve and bleed off pressure before removing safety nuts on control rods.

2. Blow out completely.

3. Hand clean with a soft wire brush.

4. Check the high and low pressure sensing ports. Clean as required. Do not use a tool that will deform the edge of the ports or change their diameter.

5. With a soft wire, rod the internal passages in the head of the Annubar.

6. Blow out instrument connections with water or compressed air.

11. Troubleshooting

Trouble	Possible cause	Investigative/corrective action
Questionable accuracy or erroneous D.P. Signal	Improper installation	Is the Annubar flow arrow pointed in the direction of the flow? Is there sufficient dtraight run upstream and downstream of the Annubar? Please refer to 4.1 in this manual for a review of piping requirments.
	System leaks	Check for leaks in instrument piping. Repair and seal all leaks.
	Contamination/plugging	Remove the Annubar and check for contamination.
	Closed valve	Verify that both Annubar valves are open. Verify that vent, equalizer, and line valves are properly positioned per the "start up procedure".
	Transmitter/Meter calibration	Is the transmitter calibration too high or low for the DP signal, "zero the transmitter"?
	Transmitter/Meter connections	Verify the high side of the transmitter is connected to the high side of the Annubar. Check same for low side.
	Entrapped air (liquid applications)	Are there uneve water legs caused by air entrapment in the instrument connections? If so, bleed air.
	Annubar misalignment	Misalignment of the Annubar will cause an erroneous signal. Refer to 4.2 in this manual for limits and guidelines.
	Opposite support Annubar	If the Annubar is an opposite side support model (-16, -26, -36, -46), is it installed through the pipe wall into the support plug?
	Operating conditions	Do the operating conditions agree with those given to Dieterich Standard? Check the flow calculations and the fluid parameters for accuracy. Double-check pipe inside diameter for proper Annubar sizing.
Spiking DP signal	Two-phase flow	The Annubar is a head mesurement device and will not accurately measure two-phase flow.
	Excessive vibration	Check impulse piping for vibration. If excessive vibration is present signal spiking is possible.

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Dieterich Standard
A DOVER Industries Company
Flow Measurement Systems

Eagle Eye Flow Meters

Installation & Operating Instructions

Contents

1. Inspection

Carefully unpack your Eagle Eye meter and inspect it as soon as it arrives. Any shortages should be reported immediately to your supplier and any damages reported to the delivering carrier.

2. Temperature and pressure limitations

The maximum fluid temperature and pressure limits for both permanent and portable meters using air and water applications are:

Meter Body Temperature Permanent and Portable Meters			
°F	psi	°C	Kpa
40-100	225	4-38	1551
100-140	150	38-60	1034
140-180	75	60-82	517

Water Line Temperature*	
Permanent Meters Maximum temp/press (nylon hose, brass valves)	130°F/225psi 54°C/1551Kpa
Portable Meters Maximum temp/press (Standard portable hoses)	210°F/225psi 99°C/1551Kpa
*Meter must be bled with cool water before each use.	

3. Selecting mounting locations

Accurate performance of both the Eagle Eye Meter and the Annubar primary flow sensor depends on proper mounting locations. For Industrial Annubar information and installation instructions, refer to DS-1001; for Commercial Annubar see DS-3001.

The distance between the meter and the Annubar flow sensor should be as short as possible. If the distance is under 50' (15m), ¼" (6mm) OD tubing is satisfactory.

The following is a checklist of general practices for connecting instrument tubing.

1. Connecting tubing must have a slope of at least 1" (25mm) per foot (30cm) and must be supported over its entire length to prevent sagging.
2. The two connecting lines should be run close together to maintain equal temperatures.

   CAUTION: Be sure nylon or rubber lines are kept away from hot lines or other heat sources.

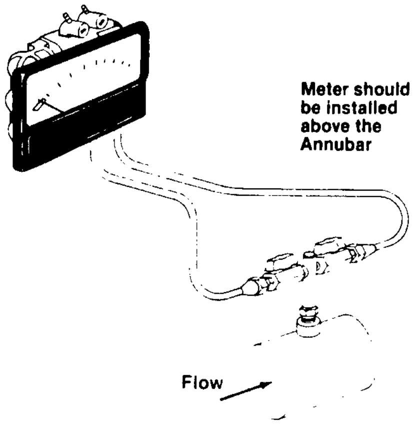
3. Run tubing where it will be accessible for maintenance.
4. Tubing must be absolutely air-tight. If vibration is expected, set up a periodic inspection procedure for checking all joints for leakage.

Do not make actual connections until Section 5, Operating Instructions.

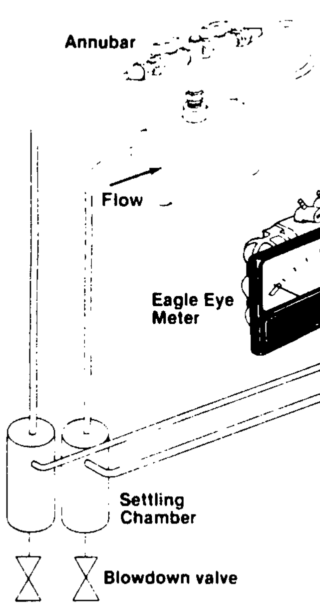
3. Selecting mounting locations (continued)

Air applications

It is best to mount the meter above the Annubar. This prevents condensation buildup.

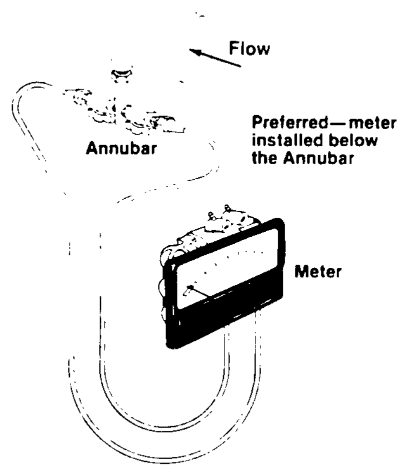


If the meter must be mounted below the Annubar, a settling chamber should be used. Instrument lines must slope down from the Annubar and down from the Eagle Eye toward the settling chamber. Liquid should be periodically drained from the traps.

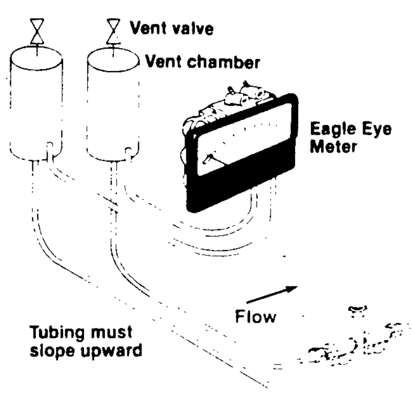


Water applications

Installation of the Eagle Eye below the Annubar is preferred for water service. Trapped air in the system is responsible for the majority of problems associated with water flow measurement. Differential pressure must be transmitted from the Annubar to the meter through a solid head of water.



If the meter must be mounted above the Annubar, a vent chamber and valve should be used. Instrument lines must slope upward from the Annubar and upward from the Eagle Eye meter toward the vent chamber.



Special applications

The magnetic coupling in the Eagle Eye Meter prohibits its installation in any strong magnetic field, e.g., near large generators, motors, etc.

Flow containing particles that are attracted to a magnet must be prevented from entering the Eagle Eye Meter. Collections of these particles on the magnet in the interior of the meter are almost impossible to flush and will eventually affect meter accuracy. Traps or screens should be installed in the instrument line between the meter and the sensor.

When the flowing fluid is dirty (containing moisture if air, or dirt on water applications), traps or settling chambers should be installed in the connecting tubing. Sediment should be periodically cleaned from the traps. Strainers are available from the factory. Refer to the drawings under water and air applications showing vent valves and settling chambers.

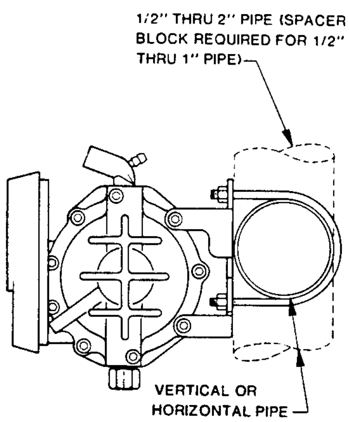
4. Eagle Eye installation

Permanent meters (Drawing C-9800)

Permanent meters must be installed with the dial face in a level vertical position. Use a level to check this. If the meter is to be used in any other position, recalibration is required.

Pipe mounting

The Eagle Eye can be mounted on any rigid vertical or horizontal pipe of ½" to 2" (13mm-51mm) diameter. A wood spacer of 2"x4"x3/4" (51mm x 10cm x 19 mm) is required for mounting on pipes of ½" to 1" (13mm-25mm). Screw holes are provided in the pipe mounting bracket for attaching the spacer. Insert the two "U" bolts provided through the large holes in the meter bracket for this type of mount.

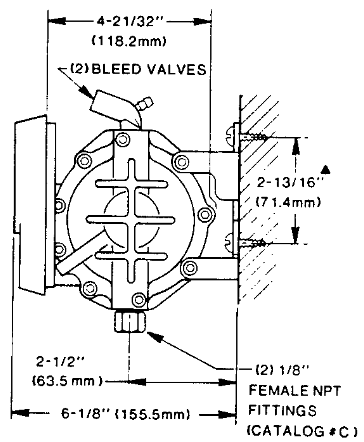


Wall mounting

The Eagle Eye may be wall mounted by removing the mounting bracket from the meter in order to give access to the two 3/16" (5mm) holes in the bracket. **Remove only the two flange bolts attaching the bracket to the meter body.** When the meter is reattached to the bracket, make sure the bracket is oriented correctly.

The long arm of the bracket attaches to the top of the meter.

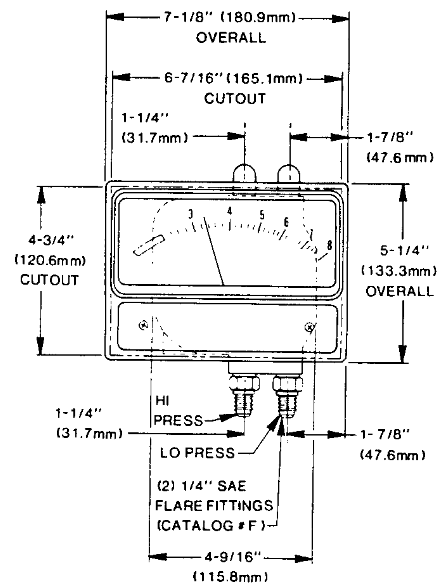
Torque the flange bolts to only 36 lb-in (4.1N•m), which is equivalent to tightening securely with a 4" (10cm) long Allen wrench.

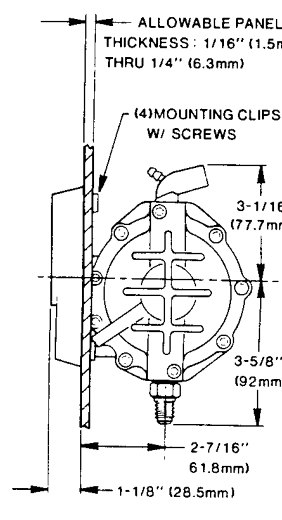


▲ – HORIZONTALLY & VERTICALLY

Flush panel mounting

Clips are furnished for flush panel mounting. The meter can be flush mounted in panels 1/16" to ¼" (2mm-6mm) thick. The exact panel cutout size is 4-3/4" (12.1cm) high by 6 7/16" (16.4cm) wide.

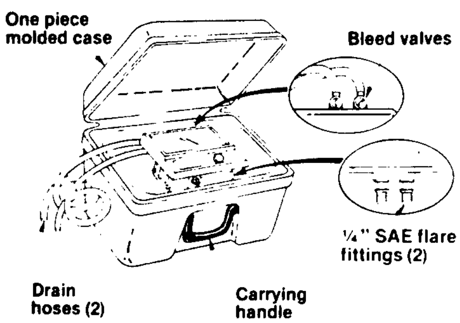


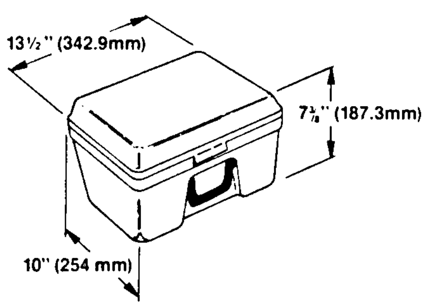


5. Operating instructions

Portable meters (Drawing C-9810)

Portable meters must be used with the dial face in a vertical position. Use in any other position requires recalibration.





Initial set-up

Mount the meter in the required vertical position, but do not connect it to the Annubar. Remove the cover access plate by unscrewing the two front cover screws and gently prying the cover from the right side. This gives access to the equalizer valve.

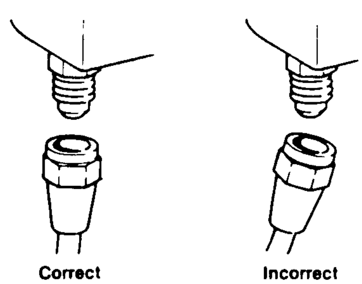
NOTE: Portable meters come with an external equalizer knob as standard.

Equalizing system

The equalizer valve provides a path between the high and low pressure sides of the meter. Clockwise rotation of the equalizer screw closes the equalizer valve, counterclockwise rotation opens it. Full closed to full open requires 1½ to 2 turns. The equalizer valve is used during the bleed procedure which follows.

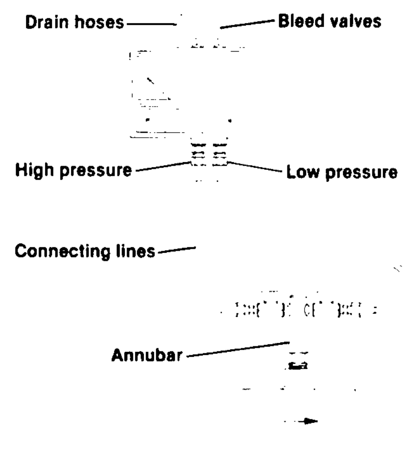
Connecting hoses to meter

Close all system valves. Insuring that all connections are installed correctly, secure connecting tubing to the meter. Use an open end wrench to hold the meter fittings from rotating while making the connections.



Connecting hoses to Annubar

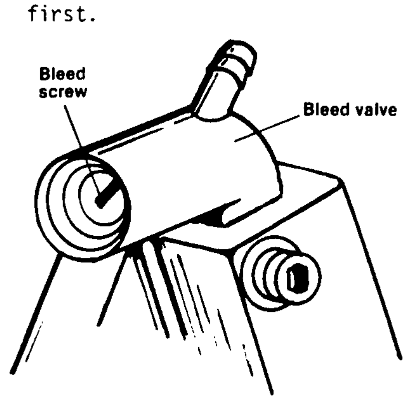
Close all Annubar valves if not already closed. Connect the meter tubing to the Annubar following the general practices for connecting instrument tubing, Section 3, page 1. Be sure to connect the high pressure side of the meter to the high pressure side of the Annubar and likewise on the low pressure side.



Bleeding instructions:

(For water service only.)

1. Install plastic drain tubing onto bleed valves and run tubing to a drain.
2. Place meter face in a vertical position.
3. Open the equalizer valve.
4. Open both bleed valves one turn counter-clockwise.
5. Open the Annubar low pressure valve slowly and just enough to send a slow, but constant stream of water through the Eagle Eye.
6. Similarly open the Annubar high pressure valve.
7. When the water exiting the bleed valves is free of air, close both bleed valves, low side first.



6. Removal from service
7. Trouble-shooting

8. Slowly close the equalizer, replace the access plate and the meter is in operation.

   NOTE: The pointer may register above zero even though the equalizer is open. This indicates the pressure drop across the equalizer.

   The meter must be bled after each system shutdown.

To take readings

AIR APPLICATIONS: any water or condensate must be drained from the connecting tubing and meter before using.

WATER APPLICATIONS: all air in connecting lines and meter must be bled with cool water before taking readings.

1. Open the equalizer valve.
2. Slowly open the Annubar low pressure valve. Check system for leaks. Any leaks in the tubing, meter, or Annubar valves will render any readings useless. Repair all leaks before proceeding.
3. Open the Annubar high pressure valve.
4. Close the equalizer valve slowly. If meter needle begins to travel beyond the meter scale maximum, open equalizer valve, close Annubar valves. The signal is too high for the meter calibration.
5. Meter is now in service.

Calibration

The Eagle Eye Meter is calibrated at the factory and should not be recalibrated in the field.

The full scale calibration point is shown on the back of the meter. See the slot opposite "Scale/Range: on the black and silver tag.

CAUTION: Do not open the meter body.

6. Removal from service

Shut the system valves at the Annubar, then open the equalizer valve and disconnect the tubing.

If the meter will be exposed to freezing temperatures, all water must be drained from the meter.

When using multiple sensors with one portable meter, valves on each Annubar should be briefly opened, then closed, to remove any air that may have accumulated. Rebleeding of the meter on water applications is unnecessary unless air has entered the tubing or meter.

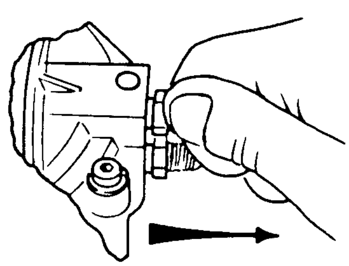
7. Trouble-shooting

Leakage

Check for leaks by shutting the Annubar valves with the Eagle Eye on the line and the equalizer closed. Any leaks will be indicated by a continuous pointer movement. If the pointer moves downscale, there is a leak in the high pressure instrument line. If the pointer moves upscale, there is a leak in the low pressure instrument line.

If a leak cannot be located, the meter should be returned to the factory.

If leakage occurs at the pressure fittings or bleed valves, replacement may be necessary. To remove a bleed valve or pressure fitting, first remove the retaining bolt that locks the fitting to the meter body. Then pull the valve or fitting from the meter. Install a new fitting or valve (always use a new O-ring); replacements may be ordered from the factory. When replacing the retaining bolt, torque the bolt to only 36 lb-in (4.1 N•m), which is equivalent to tightening securely with a 4" (10cm) long Allen wrench.



Pull outward to remove

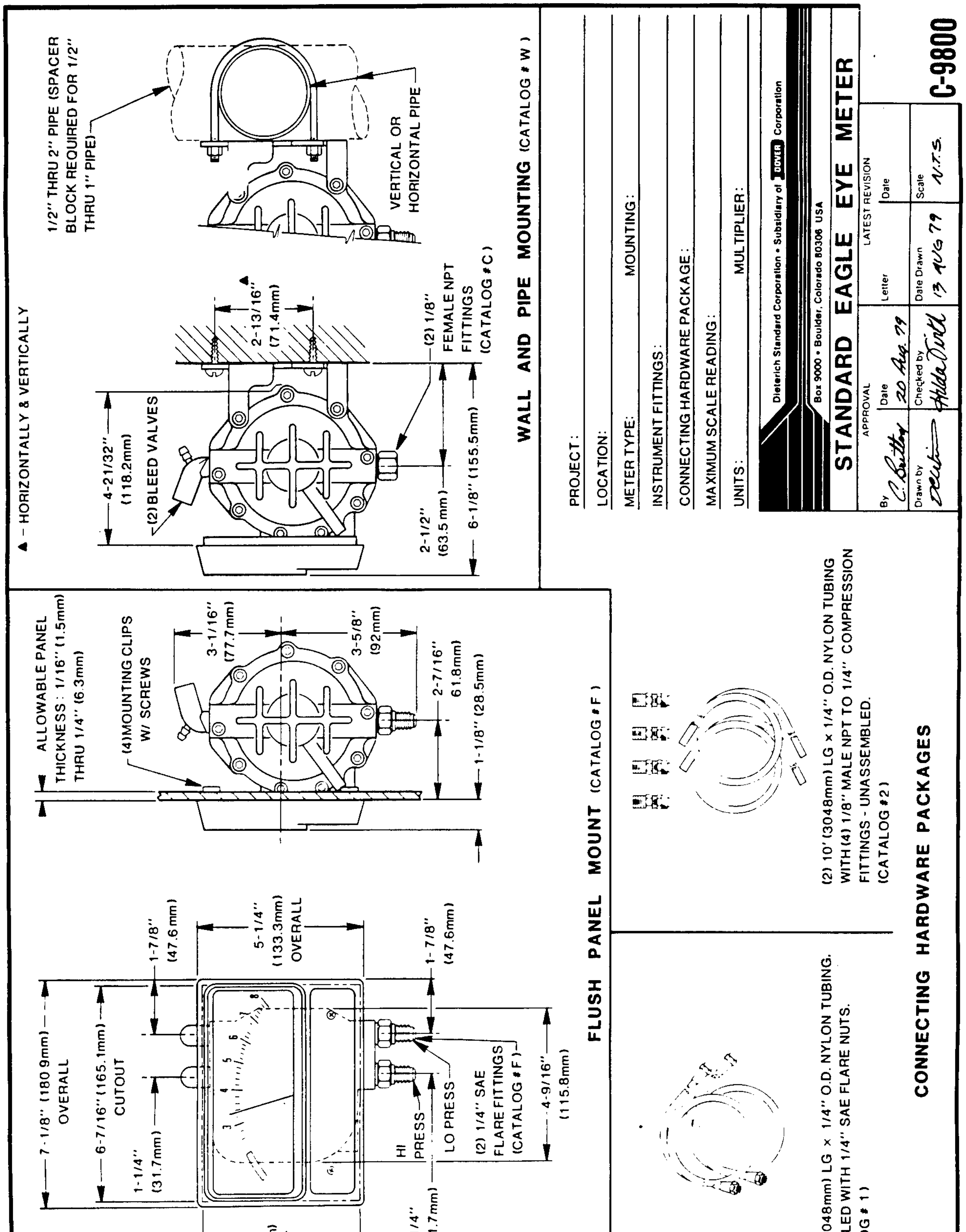
If leakage occurs at the main body seal, tighten the flange bolt nuts around the body. Do not exceed 36 lb-in (4.1 N•m) of torque, or the equivalent of tightening very securely with a 4" (10cm) long Allen wrench.

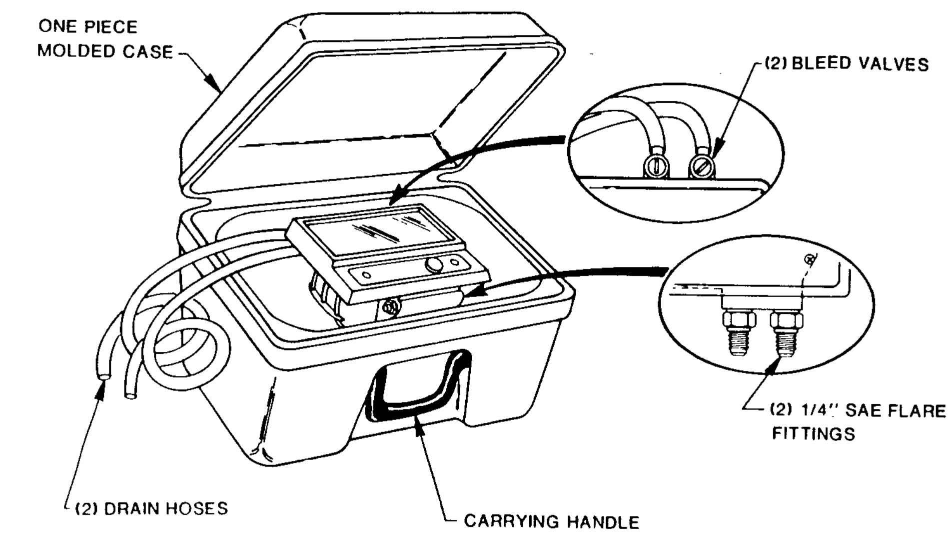
Accuracy discrepancy

The Eagle Eye Meter is one part of the complete system required to provide accurate flow measurement. Accuracy discrepancies may result from other components of the measuring system, sizing errors in ordering or problems external to the meter. Check all components in the system for proper sizing, installation and leakage.

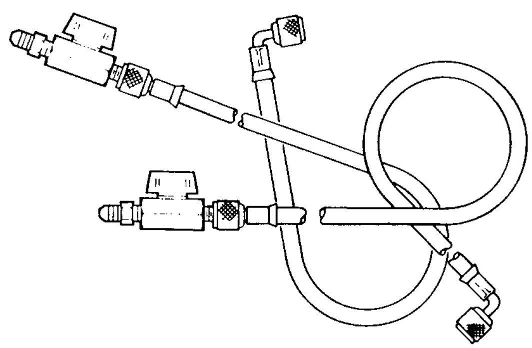
The operating environment must correspond with the specified conditions stated when the Eagle Eye Meter was ordered. If the meter is being used at different operating temperatures or pressures, or different orientation, recalibration must be done at the factory.

10. Submittal drawing

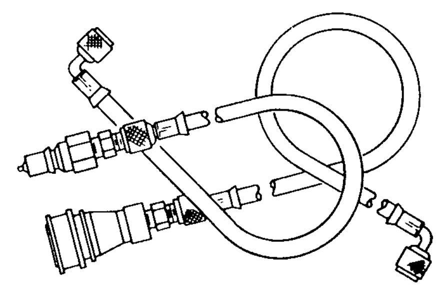




PORTABLE CASE OPTION (CATALOG #P)

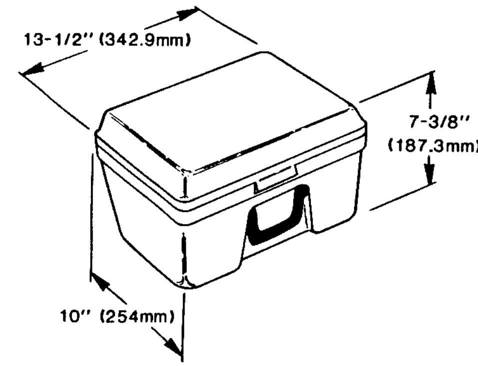


(2) 12' (3658mm) LG RUBBER HOSE WITH BRASS VALVE FOR CONNECTING TO 1/4" SAE FLARE. (CATALOG # 3)



(2) 12' (3658mm) LG RUBBER HOSE WITH QUICK DISCONNECTS. (ONE EACH - MALE & FEMALE) (CATALOG # 4)

CONNECTING HARDWARE PACKAGES



PROJECT :

LOCATION :

METER TYPE :

CONNECTING HARDWARE PACKAGE :

MAXIMUM SCALE READING :

UNITS : MULTIPLIER :

Dieterich Standard Corporation • Subsidiary of DOVER Corporation

Box 9000 • Boulder, Colorado 80306 USA

EAGLE EYE PORTABLE OPTION

APPROVAL		LATEST REVISION	
By C. Brittory	Date 24 Aug. 79	Letter	Date
Drawn by D.C.Usto	Checked by Hilda Dirth	Date Drawn 20 Aug 79	Scale N.T.S.

C-9810

Eagle Eye with the on-off control option

On-off control option (Drawing C-9820)

The Eagle Eye On-Off Control provides two adjustable setpoints to allow switching of electrical circuits as a function of flow or differential pressure.

Options 105 and 220 are identical except for input voltage requirements. For a detailed circuit schematic, see the diagrams on pages 9 and 10.

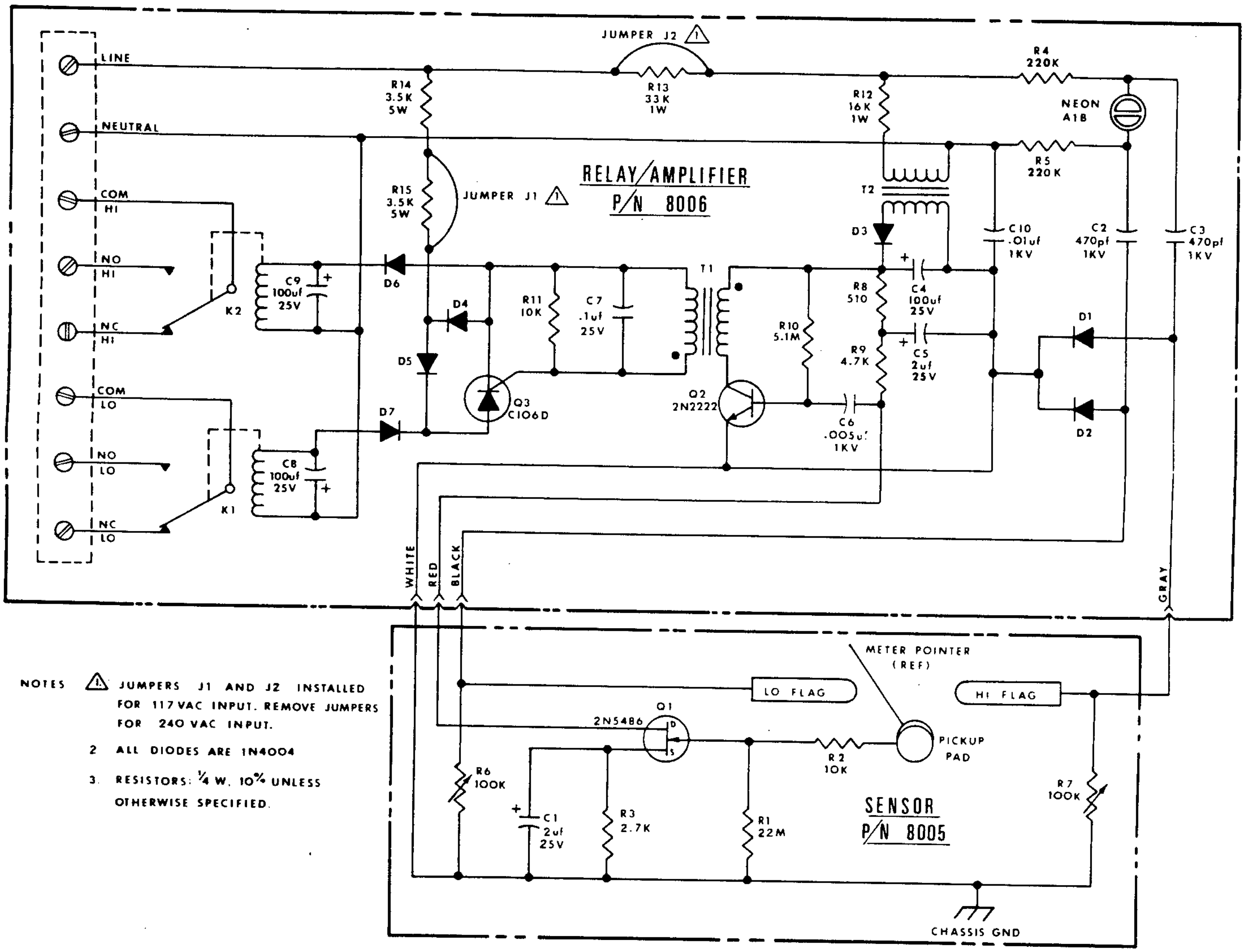
A single-pole double-throw (SPDT) load relay is provided for each of the two setpoints. The relays are deenergized when the meter pointer is between the high and low setpoints. A noncontact proximity system is utilized to sense meter pointer position and operate the appropriate relay whenever either setpoint is exceeded.

RATINGS AND SPECIFICATIONS	
Control Setpoints:	Two setpoints provided with flags to show setpoint position. Setpoints independently adjustable from under face plate.
Input Voltage Requirements:	
Option 105	105-130VAC 50/60Hz
Option 220	220-260VAC 50/60Hz
Power Consumption:	
Option 105	0.8 Watts standby (load relays de-energized) 1.9 Watts max. (load relay energized)
Option 220	1.2 Watts standby (load relays de-energized) 3.9 Watts max. (load relay energized)
Ambient Temperature Range (Operating):	+40°F to +120°F (4°C to 49°C)
Accuracy of Trip:	Operation within ±1½% FS from the setpoint position
Repeatability of Trip:	±½% FS
Deadband:	¼% FS or less (distance meter pointer must return to reset after tripping)
Minimum Difference Between Setpoints:	5%
Response Time:	½ second nominal
Connections:	Screw terminals on barrier type strip. Enclosure provided with ½" NPT conduit tap.
Load Relays:	SPDT load relay provided for each setpoint. Contact ratings shown in the table below.

LOAD RELAY: MAXIMUM ELECTRICAL CONTACT RATINGS

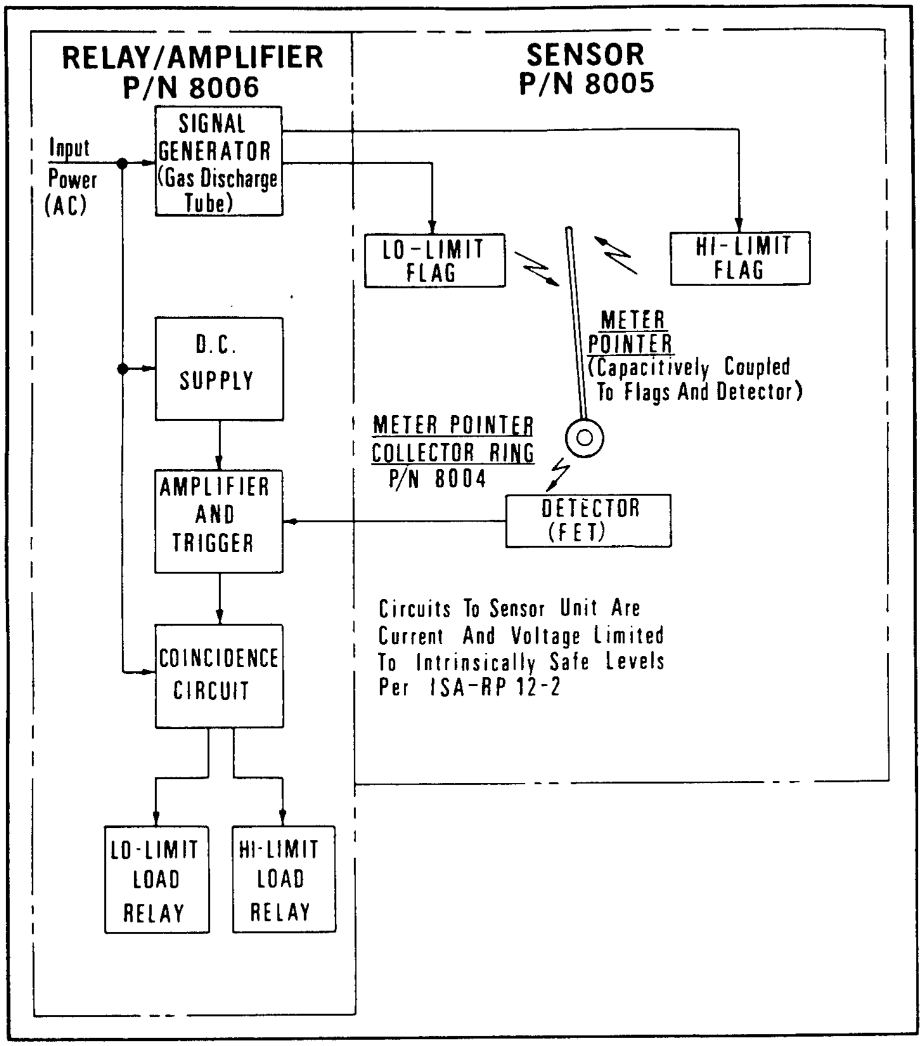
Voltage	Resistive Load (amperes)	Inductive Load (amperes)
28 VDC	5	1.5
115 VAC (50-60 Hz)	5	1.5
240 VAC (50-60 Hz)	2.5	0.75

Circuit diagram



NOTES
1. JUMPERS J1 AND J2 INSTALLED FOR 117 VAC INPUT. REMOVE JUMPERS FOR 240 VAC INPUT.
2. ALL DIODES ARE 1N4004
3. RESISTORS: ¼ W. 10% UNLESS OTHERWISE SPECIFIED.

Functional block diagram



Mounting location

See Section 3, "Mounting Locations," and include the following additional requirements:

TEMPERATURE: select a location where the ambient temperature will not exceed the specified limits for the meter relay, 40°F to 120°F (4°C to 49°C).

VIBRATION: the control will withstand a moderate amount of vibration, physical shock and handling. In general, the vibration should not exceed 2G (10-55Hz). In cases where vibration is more severe, isolation will be required to avoid output relay bounce and chatter.

HAZARDOUS LOCATIONS: the control should not be located in areas designated as hazardous per the National Electrical Code (NEC).

Electrical connections

The terminal board is reached by removing the housing cover located on the left side of the meter. A spring clip has been provided for easy removal. Electrical access to the control housing is through a ½" NPT conduit tap on the bottom of the housing.

Conduit: use of flexible conduit with strain-relief bushing is recommended. It should be supported from the panel or other suitable surface to prevent the wiring system from exerting strain on the meter. When making conduit connections, a backup wrench should be used on the hex provided at the conduit opening on the housing to prevent damage to the housing or meter mounting plate.

Terminal Board: the terminal consists of an 8-terminal barrier-type strip with wire clamps. Terminal designators are located on the left side of the strip and immediately adjacent to it. Each #4 screw terminal will accept four #18 wires or two #16 wires.

Ground: provisions for grounding of the control case consist of a #4 screw on the housing adjacent to the terminal board.

Connections: for general purpose wiring, #18 wire is recommended. The wiring may be connected to the terminals by stripping approximately 3/8" (10mm) of insulation from the wire end and then inserting the bare end under the terminal wire clamp and tightening the terminal screw. Spade terminals, ¼" (6mm) wide may also be used.

Input Power: connect as follows:

1. Connect the line or "hot" side of the single phase AC input to the top terminal designated "Line." Then connect the Neutral side of the input to the terminal designated "Neutral."
2. PROPER POLARITY MUST BE OBSERVED. In a normal 3-wire power cord, the black conductor is Line, white is Neutral, and green is ground. If input polarity is not obvious, it may be checked by connecting an AC voltmeter between one of the two input wires and ground. If the voltmeter reads nominal line voltage, the wire is "Line" or "hot." If the voltage reading is approximately zero, the wire is neutral.

NOTE: FAILURE TO OBSERVE PROPER INPUT POLARITY MAY CAUSE IMPROPER CONTROL OPERATION, BUT WILL NOT DAMAGE THE UNIT.

Ground Connection: proper grounding should always be accomplished as a matter of safety and good practice. To ground the control, install a ring-type terminal on the ground wire and connect to the control housing using the screw provided.

Load Relay Connections: connections to the load relays may be made as desired. An explanation of the terminal designators follows.

High Setpoint: the three terminals designated "Hi" refer to the high or right setpoint. This relay is deenergized and the contacts are in their normal position when the meter pointer is below (to the left of) the high setpoint.

com--relay common terminal
no --normally-open terminal (closes to common when pointer is above high setpoint)
nc --normally-closed terminal (normally-closed to common; opens when pointer is above high setpoint).

Low Setpoint: the three terminals designated "Lo" refer to the low or left setpoint of the meter. The relay is deenergized and the contacts are in their normal position when the meter pointer is above (to the right of) the low setpoint.

com--relay common terminal
no --normally-open terminal (closes to common when pointer is below low setpoint)
nc --normally-closed terminal (normally-closed to common; opens when pointer is below low setpoint.

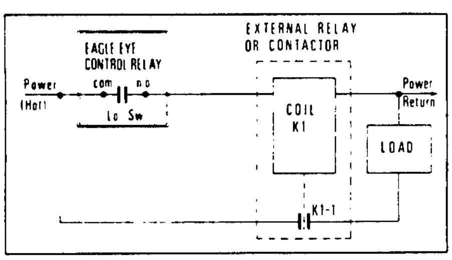
Fusing of Loads: it is recommended that loads operated by the control be fused or otherwise protected to avoid damage to the load relays and meter relay printer circuit board in the event of a short circuit. A 5 ampere slow-blow fuse is adequate for most applications.

Application data

Applications for the On-Off Control may include requirements for latching, high current, and/or time delay. Special requirements for power outage situations may also be imposed. The following paragraphs describe typical control hookups to meet such requirements.

High current loads

The two load relays provided as part of the Eagle Eye control are primarily intended for control and interlock of starters, contactors and other control devices. The relay contacts may also be used to open and close circuits to other relays and control devices. In general, relays are not used for direct control of power consuming devices except motors and solenoids which draw less than 1.5 amperes. Applications which require switching of loadsin excess of the relay contact ratings can be met by utilizing the control to operate an external relay or contactor instead of switching the load directly. This is shown below, along with a brief discussion of typical contactors and control relays.



When control relay contact closes, relay coil K1 is energized closing relay contact K1-1. The current through the control relay is only that which is required by coil K1

Contactors

For operating very heavy loads, a NEMA contactor should be used. NEMA Standard ICS-1970 lists specific ratings for AC contactors as shown below. Ratings for DC contactors are shown below also. Because copper contacts are utilized on some contactors, the current rating for each size is an 8-hr rating--the contactor must be operated at least once every 8-hrs to prevent copper oxide from forming and causing excessive contact heating. For contactors with silver or silver alloy contacts, the 8-hr rating is equal to a continuous rating. Also, this rating applies to contactors mounted in the open without an enclosure. Contactors installed in an enclosure have a rating equal to 90% of the open rating because of reduced contactor cooling.

Since contactors are frequently used to control motors, horse-power ratings are also used. Contactors must be able to interrupt (turn-off) at least six times the current corresponding to their maximum horse-power rating. Current-rated contactors must have the ability to interrupt at least 150% rated current.

Inrush current of a tungsten lamp may be 12 to 18 times its normal current. Therefore contactors are derated 20 to 50% to compensate for this inrush current. Size 00 through 1 contactors have a rating of 50% of the 8-hr open ratings, sizes 2 and 3, 60%; and sizes 4 through 6, 80%.

The contact ratings of the Control Relay are sufficient to operate the coil on most contactors, but the coil requirements should be checked before utilizing the control relay to operate a specific contactor.

Standard NEMA Ratings — AC Contactors, 60Hz

Size	8-hr Open Rating (A)	Power (hp) Three Phase 200 V	230 V	460/575 V	Single Phase 115 V	230 V
00	9	1½	1½	2	⅓	1
0	18	3	3	5	1	2
1	27	7½	7½	10	2	3
2	45	10	15	25	3	7½
3	90	25	30	50	. .	
4	135	40	50	100	.	
5	270	75	100	200		
6	540	150	200	400	. .	
7	810	. .	300	600	. .	
8	1,215	.	450	900	.	
9	2,250	.	800	1,600	.	

Table based on ICS2-321B-1 (Revised)

Standard NEMA Ratings — DC Contactors

Size	8-hr Open Rating (A)	Power Rating (hp) 115 V	230 V	550 V
1	25	[illegible]	5	
2	50	5	10	20
3	100	10	25	50
4	150	20	40	75
5	300	40	75	150
6	600	75	150	[illegible]
7	900	110	225	450
8	1,350	175	350	700
9	2,500	300	600	1,200

Table based on ICS 2-211

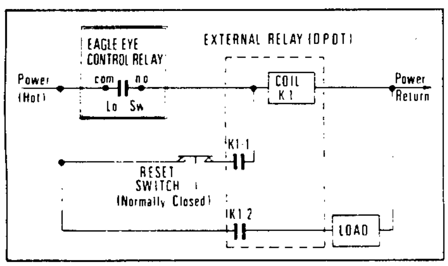
Control relays

Where the contact ratings for the control relay are insufficient for a control application, or where multiple poles are required, an external relay having the desired characteristics may be operated by the control relay. A wide variety of relays are available to suit virtually every need. The most common AC, machine tool, general purpose relay has a 10 ampere continuous rating. Usually, the contact and pole construction in a machine tool type or general use industrial relay is the same for both AC and DC. However, DC contact ratings are much lower than AC ratings.

Latching circuits

Latching requires that once a switch or relay trips, it must remain tripped until reset either manually or automatically by another control component. The Eagle Eye control may be used in conjunction with an external relay or contactor to initiate latching, or to reset a latch circuit. In addition, it is possible to initiate latching with one setpoint, and reset with the other. Typical latching and control circuits are shown below.

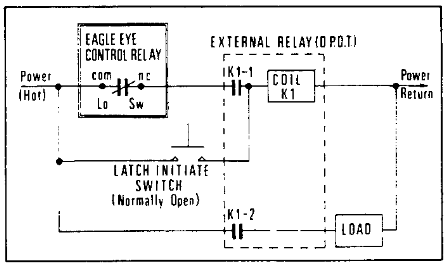
Basic Latching Circuit with Manual Reset



When control relay contact closes, relay coil K1 is energized, closing relay contacts K1-1 and K1-2. Power to energize coil K1 is then supplied through contact K1-1 and the circuit is latched regardless of whether the control relay contact is open or closed. If the control relay contact is open, the latch may be reset by interrupting the power to coil K1 using the momentary reset switch. This causes K1-1 to open. The latch may be reinitiated by closure of the control relay contact.

In the circuit shown above, power would be applied to the load if the meter pointer fell below the low setpoint. The load would remain energized even if the meter pointer then returned to a position above the low setpoint, unless manually reset.

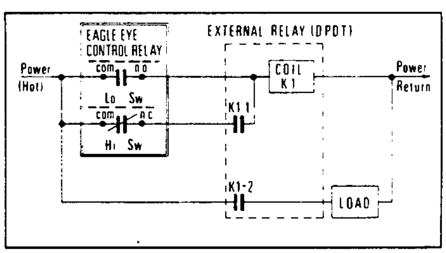
Basic Holding Circuit with Manual Latch



With the control relay in its normally closed position, closure of the momentary switch will energize relay coil K1, closing relay contacts K1-1 and K1-2. Power to energize the coil K1 is then supplied through the normally closed control relay contact and K1-1, and the circuit is latched. The latch will be broken if the control relay contact opens, and must be manually relatched.

In the circuit shown above, once power has been initiated to the load, the load will remain on unless the meter pointer falls below the low setpoint. If this occurs, the load will turn off and remain off, even if the meter pointer then returns to a position above the low setpoint.

Latching Circuit with Automatic Reset



When the low setpoint control relay contact closes, relay coil K1 is energized, closing contacts K1-1 and K1-2. Power to energize coil K1 is then supplied through the normally-closed high setpoint contact and through contact K1-1. The circuit is now latched, and will remain latched until the high setpoint contact opens.

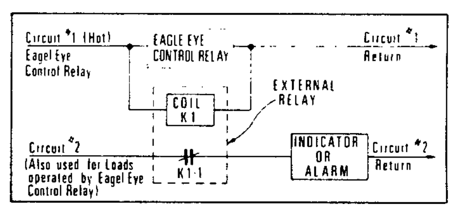
In the circuit shown above, power would be applied to the load if the meter pointer fell below the low setpoint. The load would remain energized until the meter pointer passed above the high setpoint at which point the latch would be broken. The load then remains off until the meter pointer again falls below the low setpoint.

Time delay

The Eagle Eye On-Off Control has a response time of approximately ½ second at both trip points. Applications requiring longer delay times can be met using an external time delay relay. Pneumatic, thermal and electronic types are available with either fixed or adjustable delay times. The circuits for utilizing a time delay relay in conjunction with the control relay are identical with these previously shown for external relays.

Power outage

In most applications, the same circuit used to supply input power to the control relay is also used to operate the meter relay loads. In these cases, the outage would affect the total system. However, for various reasons (voltage differences, etc.) some applications will require that the supply input for the control relay and the supply for the loads be separate. Depending on the system effect, and probability of power outage to the control relay, an indication of power outage may be required. A simple means of providing such indication is shown below.



External relay K1 is connected in parallel with the control relay. When Circuit #1 is energized, contact K1-1 is open. If a power outage occurs on Circuit #1, K1-1 will close and operate an indicator or alarm on Circuit #2.

Controls

Controls for the meter relay are mounted on the Control Sensor unit located behind the meter protective front cover (bezel). Controls consist of individual adjustments for the high and low setpoints. External control knobs which extend through the meter bezel are optional at extra cost. The setpoints are adjusted by turning the adjustment screw counter-clockwise (CCW) to increase settings, and clockwise (CW) to decrease settings. As the adjustment is turned, the setpoint flag or pointer will move to show the setpoint value on the meter scale. The minimum differential between the two setpoints is 5% FS. DO NOT ATTEMPT TO FORCE THE FLAGS CLOSER THAN 5%, OR DAMAGE TO THE FLAG MECHANISM MAY RESULT.

Note: Two potentiometers are mounted on either side of the sensor unit. These controls are utilized for control relay calibration and should not be adjusted in normal use.

Operating instructions

Instructions for the basic Eagle Eye meter are unchanged for meters equipped with the On-Off Control. The only additional instructions required for the On-Off Control are to apply power, and adjust the high and low setpoints as desired. Notes pertaining to control operation are included below.

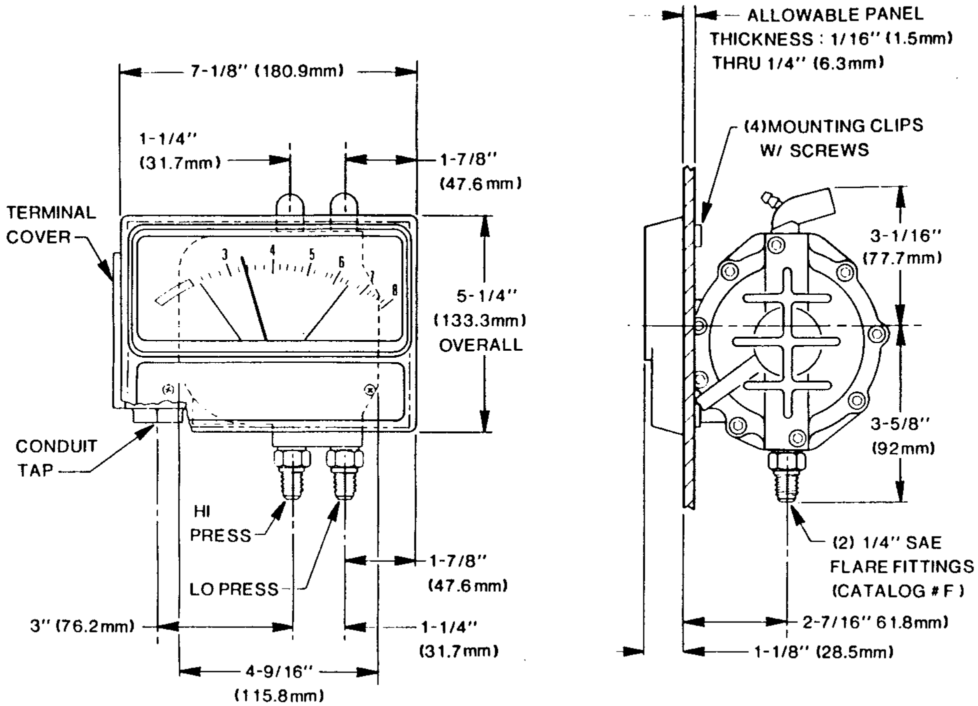
Operating Notes:

1. Initial Power Application: both load relays are normally de-energized when the meter pointer is between the two setpoints. Therefore, power application under this condition will have no effect on the relays. If the meter pointer is above the high setpoint or below the low setpoint, the appropriate relay will energize approximately ½ second after power application due to the system response time.
2. Input Voltage Transients: the On-Off Control is highly immune to transients and noise on the input power lines. In extremely severe applications, however, the use of a line filter may be required.
3. Accuracy: accuracy refers to the error between the indicated setpoint as shown by the control setpoint flags and the actual setpoint. The specified accuracy of ±1½% FS applies to the conditions of 70°F (21°) ambient temperature and nominal input line voltage. Variations in ambient temperature and/or line voltage will affect accuracy slightly; however, repeatability at a given set of conditions will remain within ±½% FS.

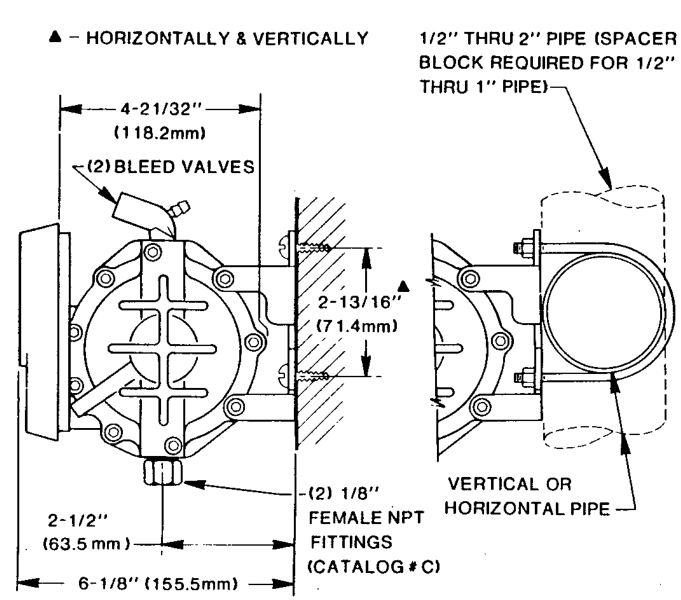
   Line Voltage Variations: setpoint accuracy will be affected by approximately ½% when the control is operated at specified voltage extremes.

   Ambient Temperature Variations: setpoint accuracy will be affected by approximately 1% when the control is operated at specified temperature extremes.

   Accuracy is also slightly affected during the initial 5 minute period following power application while the circuit stabilizes.
4. Response Time: both setpoints incorporate a delay of approximately ½ second. Therefore, when checking accuracy, it is important to approach the setpoint SLOWLY to negate the time delay effect and obtain a true reading.
5. Ambient Electrical Noise: the control is highly immune to most ambient noise associated with motors, fluorescent or mercury-vapor lamps, etc. In the event that any problems are encountered, consult the factory.

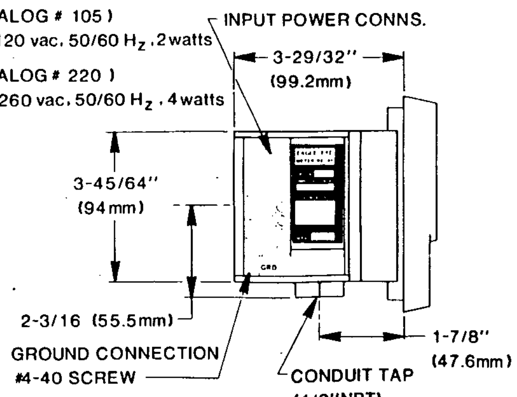


FLUSH, PANEL MOUNT (CATALOG # F)



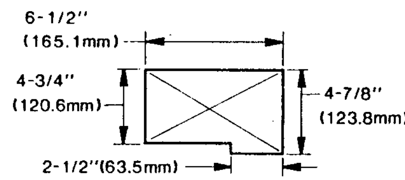
WALL AND PIPE MOUNTING (CATALOG # W)

(CATALOG # 105)
105-120 vac, 50/60 H_Z, 2 watts
(CATALOG # 220)
220-260 vac, 50/60 H_Z, 4 watts



TERMINAL COVER NOT SHOWN

WIRING INTERFACE



PANEL CUTOUT

CONNECTING HARDWARE

(2) 10' (3048mm) LG × 1/4" O.D. NYLON TUBING, ASSEMBLED WITH 1/4" SAE FLARE NUTS. (CATALOG # 1)

(2) 10' (3048mm) LG × 1/4" O.D. NYLON TUBING WITH (4) 1/8" MALE NPT TO 1/4" COMPRESSION FITTINGS - UNASSEMBLED. (CATALOG # 2)

PROJECT:
LOCATION:
METER TYPE: MOUNTING:
INSTRUMENT FITTINGS:
CONNECTING HARDWARE PACKAGE:
MAXIMUM SCALE READING:
UNITS: MULTIPLIER:
INPUT VOLTAGE :

Dieterich Standard Corporation • Subsidiary of DOVER Corporation
Box 9000 • Boulder, Colorado 80306 USA

EAGLE EYE w/ ELECTRONIC RELAY

APPROVAL		LATEST REVISION	
By C. Buttery	Date 20 Aug 79	Letter	Date
Drawn by DCW	Checked by Hilda Dirth	Date Drawn 16 Aug 79	Scale N.T.S.

C-9820

Represented by:

Dieterich Standard A DOVER Industries Company
PO Box 9000
Boulder, Colorado 80301 USA
(303) 530-9600

FAX: 303/530-7064

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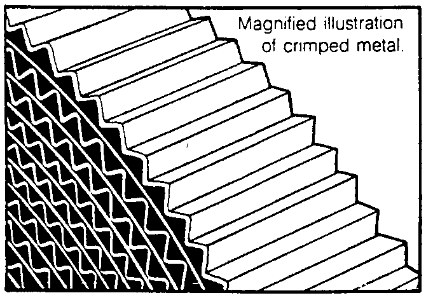
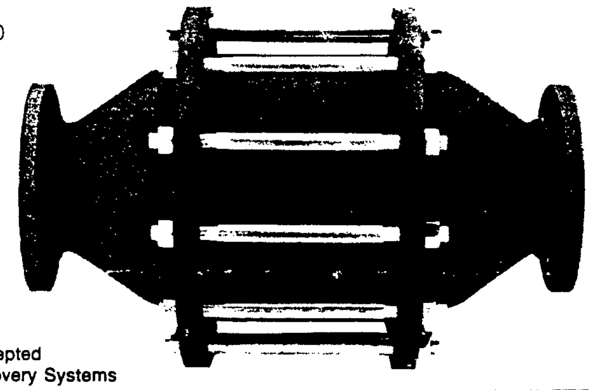
Printed in USA
DS-2200 (5/91)
Replaces DS-2200 (3/89)

Series No. 25000

Bidirectional Detonation Flame Arrester





U.S. Coast Guard Accepted for Marine Vapor Recovery Systems

Detonation Arrester with Crimped Metal Element

OBJECTIVE

The Protectoseal Series No. 25000 Detonation Flame Arrester is specifically designed to withstand and arrest the high velocity and pressure flame fronts that may develop in long or complex piping runs such as those encountered in vapor recovery or tank manifolding systems. The arresters provide positive protection against flame transmission through the piping systems handling Group D materials while allowing maximum flow efficiencies.

TECHNIQUE

When properly specified and installed, the 25000 Series Detonation Flame Arrester is designed to stop a flame front approaching from either direction even if it has transitioned to a detonation. A detonation is defined as the movement of the flame through the pipe at the speed of sound in the burnt gas. The severity of the service conditions that the Detonation Flame Arrester must withstand is demonstrated by the fact that the stable detonation velocity of a flame front in a 4.3% propane/air mixture is 5800 ft/sec. Instantaneous pressures at the flame front in excess of 500 PSIG have been recorded. The Detonation Flame Arrester stops and quenches such a shock wave while retaining the integrity of both the arresting element and the housing. The size and shape of the openings in the crimped metal element and the length of passage through these openings have been designed to insure the ability of the device to quench detonations.

CONSTRUCTION

Standard: Detonation Flame Arrester housing is all welded steel construction. Crimped metal arrester element is 316 Stainless Steel encased in a steel element housing.
Custom: All Stainless Steel construction is available as an alternate. Other special materials of construction to withstand the corrosive action of some vapors and atmospheric conditions are available on request.

SPECIAL FEATURES

Durability: Because of the severity of the service conditions that a Detonation Flame Arrester encounters, the housings are welded steel fabrications. All welding performed in accordance with ASME Boiler and Pressure Vessel Code Section VIII. All welding procedures in accordance with ASME BPV Code Section IX.
Housing hydrostatically tested at 475 PSIG.

Precision Manufacturing: The crimped metal element design allows for accurate and consistent production capabilities necessary to insure proper functioning of the Detonation Flame Arrester.

Optional Fittings: Flanged or tapped fittings may be provided on housing for drains, pressure taps or temperature probes if required.

Numerous Sizes Available: Standard connections are 150# A.N.S.I. R.F. flanges. Available in 2" through 24" sizes. Use chart on reverse side for ordering.
Quality Assurance: Each unit is factory inspected prior to shipment to meet Protectoseal's high standards.

MATERIALS OF CONSTRUCTION

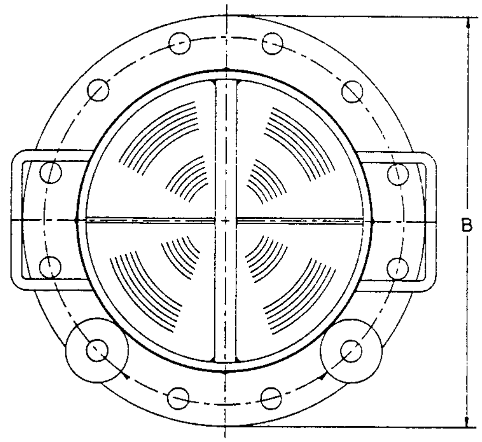
Series	Housing & Element Housing	Element
C25000	Steel	316 Stainless Steel
F25000	316 Stainless Steel	316 Stainless Steel

All units flanged to mate with 150# RF A.N.S.I

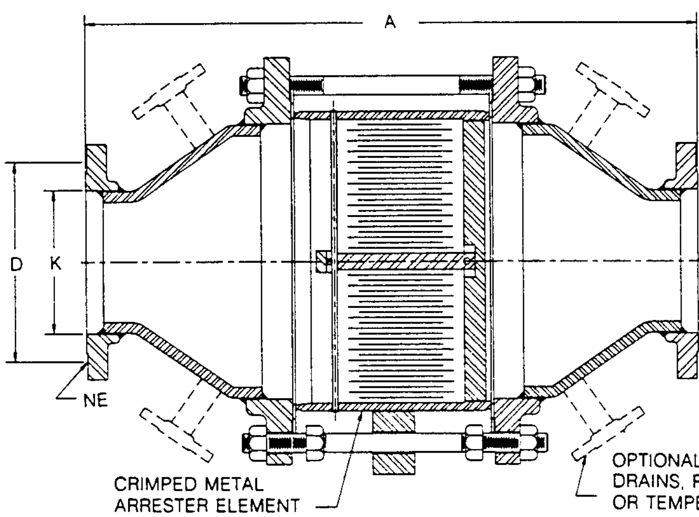
SPECIFICATIONS

Series No. 25000
Bidirectional Detonation Flame Arrester

END VIEW SHOWING ARRESTER ELEMENT



SIDE VIEW



SERIES NO. 25000

DIMENSIONS

Standard Construction						
Cat. No.	K Pipe Size	A(± ½") Face to Face	B Diameter	D B.C.	N No. of Holes	E Hole Dia.
25002	2"	15⅞"	9"	4¾"	4	¾"
25003	3"	19¾"	11"	6"	4	¾"
25004	4"	21½"	13½"	7½"	8	¾"
25006	6"	28⅞"	19"	9½"	8	⅞"
25008	8"	44"	23½"	11¾"	8	⅞"
25010	10"	57¼"	27½"	14¼"	12	1"
25012	12"	58"	32"	17"	12	1"
25016	16"	81⅝"	38¾"	21¼"	16	1⅛"
25018	18"	83⅛"	46"	22¾"	16	1¼"
25020	20"	84"	53"	25"	20	1¼"
25024	24"	84¾"	57¼"	29½"	20	1⅜

Add prefix "C" for Welded Steel Housing with 316 Stainless Steel Arrester Element encased in a Steel Housing
Add prefix "F" for 316 Stainless Steel Housing, Arrester Element and Element Housing.

Check with Sales Department for availability and scheduled delivery.

DIMENSIONS SHOWN ARE FOR REFERENCE ONLY. CONTACT FACTORY FOR CERTIFIED DRAWINGS.

APPLICATION

Series No. 25000
Bidirectional Detonation Flame Arrester

COMPANY NAME ______________________________

ADDRESS ______________________________

____

CITY ______________ STATE ______________ ZIP ______________

COMPANY CONTACT ______________________________

TELEPHONE NO. ______________ FAX NO. ______________

Vapor(s) ______________________________

Molecular Weight ______________________________

Vapor Flow Rate* ______________________________

For Stated Flow: Temperature of Vapors ______________ Pressure ______________

Operating Temperature ______________ Operating Pressure ______________

Pipe Size ______________ Flange Rating ______________
(150# R. F. ANSI Standard)

Allowable Pressure Drop Requirements ______________________________

Materials of Construction:

Housing & Element Housing: ______ Carbon Steel
______ 316 Stainless Steel
______ Other ______

Element: ______ 316 Stainless Steel
______ Other ______

Accessories (pressure or temperature tap connections, special paint, etc.) ______________________________

____

Is U.S. Coast Guard Approval for Marine Vapor Recovery Systems required? YES ______ NO ______

*If information concerning temperature and pressure of vapor flow is not stated, it will be assumed ambient conditions exist. (60°F O PSIG)

Name ______________ Title ______________

Signature ______________ Date ______________

PROTECTOSEAL RECOMMENDATION

SCFH Air Flow Equivalent ______________ Pressure Drop ______________

Pipe Size ______________ Model No. ______________

Signature ______________ Date ______________

ALLIED FLARE, INC.

OPERATION MANUAL
FOR
JACOBS ENGINEERING

JOB# 629

OPERATING MANUAL - AIRFLARE

This flare is equipped with a blower which supplies combustion air at the flare tip. The flare tip is designed to provide a smokeless burning of the specified flaregas at design rates of flow.

The flare is designed to operate with the fan in continuous operations. A poor flame pattern and possible damage to the burner will result if the flare is operated without the blower.

The flare should be commissioned as follows:

1. Test to confirm that there is not an explosive mixture of gas and air in the flare stack.

2. Ensure that the spike gas manual gate valve is closed.

3. Turn on the pilot fuel gas with spike gas on switch (black button next to flare control panel).

4. Light the pilot by turning the hand-auto switch to either position. For continuous operation, turn switch to auto position.

5. Confirm that the pilot is burning.

6. Turn on the air blower.

7. Establish airflow from the bluebox.

8. If VOC concentration in exit air from bluebox cannot sustain smokeless combustion, open spike gas manual gate valve on flare.

9. For emergency shutdown, turn off spike gas (red button next to flare control panel).

10. An emergency strobe light has been put on the flare. If the pilot power is on and the pilot switch is in either the auto or hand position, and is trying to light the pilot, the strobe light will be on. Once the pilot flame is established, the light will turn off automatically. If there is no pilot fuel (propane runs out) and the pilot igniter is still trying to light the pilot, the light will turn on.

Consult the operating instructions for the control panel, pilot ignition and stack operating sections for further information.

If problems are encountered or further information is required, call:

Allied Flare, Inc.
Flare Division Engineering Dept.
(713) 332-1000

FLARESTACK GUY SUPPORTED STACKS

Small Guy Supported Stacks

This flare is designed to mount on a base foundation supplied by others. Check the base bolt arrangement to confirm that the bolts align with the holes in the stack base.

The base bolts should be equipped with jack nuts or shims so that the stack can be levelled and plumbed.

Orient the stack on the base as shown in the drawings so that the flaregas inlet and utility connections are in line with the customer's supply connections.

Assemble and connect the guy wires as shown in the erection drawings. Check the anchor locations and oriented properly. Follow Allied Rigging Procedures for connection, tensioning and plumbing the stack.

The stack base should be shimmed and may be grouted at this time. Grounding of the stack and guy wires is recommended.

Safety wire should be installed on all turnbuckles to insure they retain their adjustments.

Touch up painting and cold galvanizing should be applied as needed to the stack, bolts, turnbuckles and fittings.

The stack supply connections should be free of stress or thrust on the stack. Safe procedures must be followed to insure that all hydrocarbon and utility lines are in a safe condition while connections are being comleted.

The stacks flaregas line must be blinded and tested free of hydrocarbons during this work.

The pilots must be ignited and burning before the flare is put into service. The flare should be purged with nitrogen or other inert, noncondensing gas to purge the air from the system before gas is admitted.

If there is any possibility of a conbustible mixture of gas and air being present in the flaregas line or stack, a liquid seal, detonation arrester or flame trap must be present at the base of the flare.

The flarestack purge gas flow must be established for a time sufficient to purge the air from the stack before the flaregas line is put into service.

If there are any questions or more information is needed, call:

Allied Flare Inc.
(713) 332-1000
Houston, Texas

instalin.man
jc 6/26/92

OPERATING MANUAL - AIRFLARE CONTROL PANEL

The control panel includes the pilot ignition systems, pilot monitors, display/alarm lights and the blower control.

This panel is equipped with an automatic pilot relight and monitoring system. The thermocouple relay monitors the pilot burner and indicated pilot failure via a red light on the panel. The ignition system is automatically actuated when the pilot failure is detected. When the pilot relights, the light will go out. A remote alarm can be actuated via the extra alarm contacts provided.

The ignition system consists of an arc ignitor mounted in the pilot burner windshield at the flaretip. The ignitor can be operated manually by pushing the red "IGNITE" button.

The fan is operated via the fan control switch on the control panel. This fan is a single speed, on-off, air blower. The fan must be turned on before the flare is put into service.

Consult the drawings and installation instructions for details of this equipment.

If additional informations is required call:

Allied Flare, Inc.
Flare Division Engineering Dept.
(713) 332-1000

cpanalop.man
6/26/92

INSTALLATION INSTRUCTIONS - PILOT BURNER/ARC IGNITION

The pilot burners are designed for ease of installation and rugged service. The pilot burners are designed to burn constantly. These "pilots" provide reliable ignition of the waste gases at the flare tip.

Each pilot consists of a 1-1/2" fuel gas and air mixer which is welded to the burner tip at the top of the 1-1/2" supply pipe. The mixer consists of an orifice spud in the threaded hole of the 1-1/2" fuel inlet flange.

These pilots are equipped with an electric igniter. The Allied Arc Igniter consists of an 8" tall 3" stainless tube which connects the Arc Electrode to the Arc Transformer in a stainless NEMA 4X enclosure 8' below the flare tip. The Arc is a high voltage spark ignition which is positioned to light the pilot burner and also provide a secondary means of lighting the flare tip in the event the pilot burner is extinguished.

The position of the Arc Electrode and the pilot windshield must be as shown for proper operation, adjust as needed. Do not bend the electrode, loosen the U-bolt and move the 3" Arc tube to adjust the gap.

The 3" tube(head) is lined with a solid ceramic insulator, do not bend, hammer or flex the tube or the insulator will be damaged.

NOTE: Use 1/8" asbestos or flexitallic gaskets on these and all other flanged connections on the flare tip.

NOTE: Be certain that both supply pipes have been "blown clean" before connecting to flare and installing fuel gas strainer.

The fuel gas supply riser should be connected to a regulated (10-15 psig) fuel gas supply pipe at the base of the flare tower.

The pilots should be tested to confirm that the connections are correct and that they can be ignited and will burn steadily. DO NOT test pilots while workman are near flare tip.

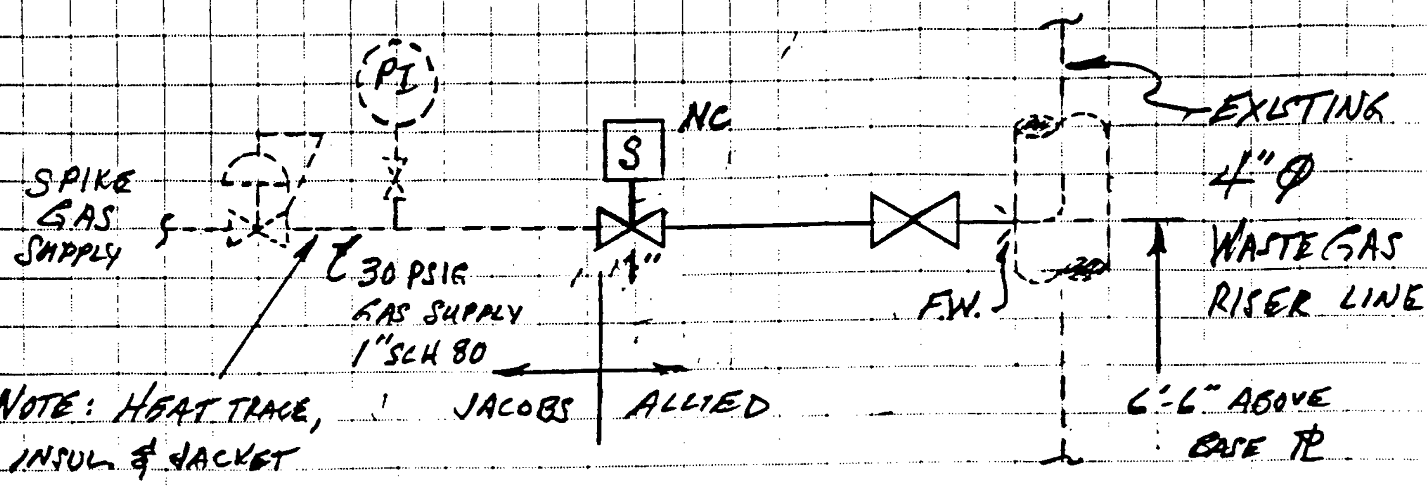
The pilots burn with a 4" clear blue flame which is nearly invisible in daylight. The pilot flame can be observed at dark (binoculars are helpful).

For further information call:

Allied Flare Inc.
(713) 332-1000
Flare Division Engineering Dept.

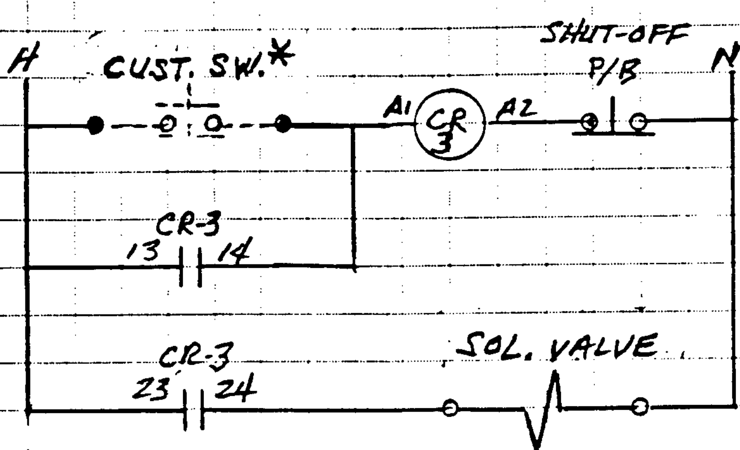
ALLIED FLARE INC.
P.O. Box 58294
HOUSTON, TEXAS 77258
(713) 486-7631

JOB ____
SHEET NO. 1 OF 1
CALCULATED BY GJM DATE ____
CHECKED BY ____ DATE 8-3-93
SCALE N.T.S.



NOTE: HEAT TRACE, INSUL. & JACKET AS REQUIRED TO MAINTAIN FLOW.

P & I D – SPIKE GAS ADDITION



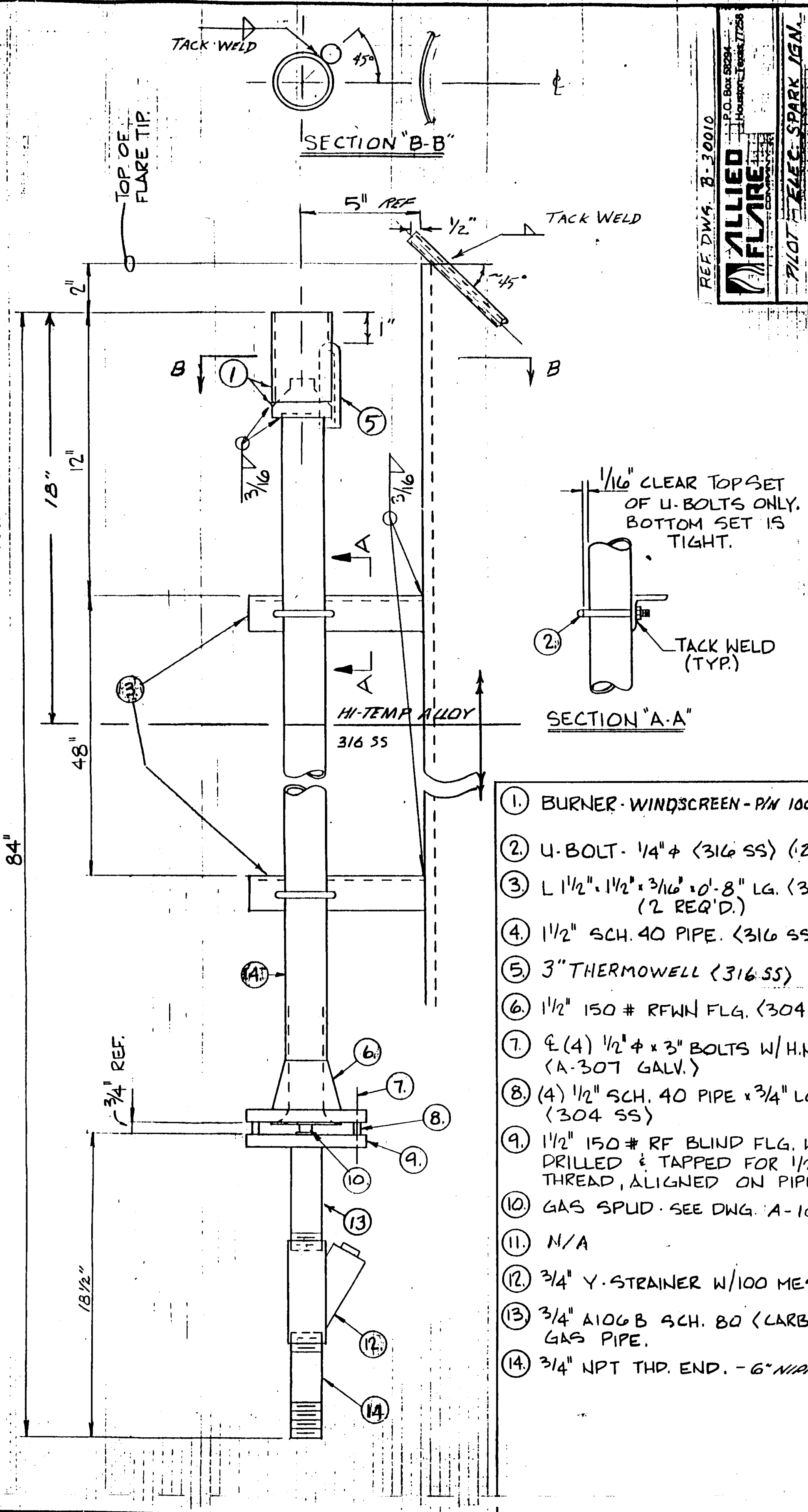
*CUSTOMER SWITCH DEVICE TO BE NORMALLY OPEN – MOMENTARY CONTACT TYPE.

LADDER LOGIC DIAGRAM

MATERIAL SUPPLIED BY ALLIED FLARE:

- INJECTION SPOOL W/ BLOCK VALVE AND NIPPLES
- 1" SOLENOID VALVE, NORMALL CLOSED, BRASS BODY, NEMA 7
- CONTROL RELAY, CR-3
- SHUT-OFF P/B W ENCLOSURE, NEMA 7/9 & COND. SEAL (2).

PRODUCT 204-1 NEBS Inc., Groton, Mass. 01471.



1. BURNER - WINDSCREEN - P/N 10015 & 11100.
2. U-BOLT - 1/4" ⌀ (316 SS) (2 REQ'D.)
3. L 1 1/2" x 1 1/2" x 3/16" x 0'-8" LG. (316 SS) (2 REQ'D.)
4. 1 1/2" SCH. 40 PIPE. (316 SS)
5. 3" THERMOWELL (316 SS)
6. 1 1/2" 150 # RFWN FLG. (304 SS)
7. ℄ (4) 1/2" ⌀ x 3" BOLTS W/ H.N. & PALNUT (A-307 GALV.)
8. (4) 1/2" SCH. 40 PIPE x 3/4" LG. SPACER (304 SS)
9. 1 1/2" 150 # RF BLIND FLG. W/ HOLE DRILLED & TAPPED FOR 1/2" x 13 UNC THREAD, ALIGNED ON PIPE ℄.
10. GAS SPUD - SEE DWG. A-10011
11. N/A
12. 3/4" Y-STRAINER W/100 MESH SCRN.
13. 3/4" A106 B SCH. 80 (CARBON STEEL) GAS PIPE.
14. 3/4" NPT THD. END. - 6" NIPPLE

REF. DWG. B-30010

ALLIED FLARE COMPANY
P.O. Box 58294 Houston, Texas 77258

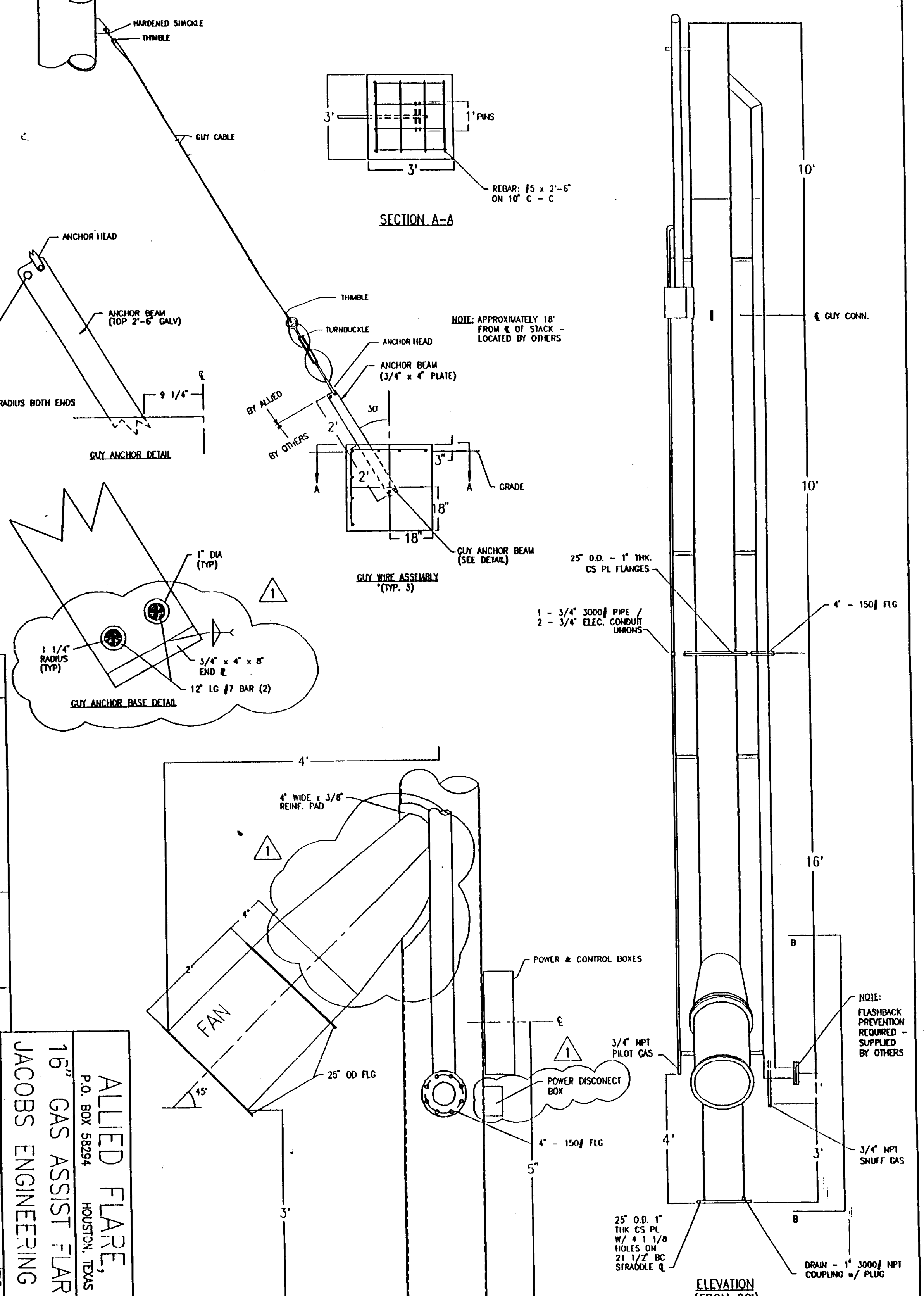
PILOT - ELEC. SPARK IGN. GENERAL ASSEMBLY

DRAWN BY	SCALE	DATE	W.O.#	DRAWING NO.
GLM	NTS	6-5-92	0629	B-31195

NO.	DATE	REVISION	BY
0	6-5-92	ISSUED FOR APPROVAL	

MATERIALS					
ELEV.	GUY SIZE	SHACKLE	GRIP	TURNBUCKLE	THIMBLE
30'	3/8" EHS	5/8"	3/8"	3/4"	7/16"

NOTES: SEE DWG. 31198 FOR TIP GENERAL ARRANGEMENT



* - TRUE NORTH ORIENTATION TO BE DETERMINED/PROVIDED BY CUSTOMER

REV #	REVISION DESCRIPTION	DATE	BY
1	AS BUILT	9/08/92	GM
0	FOR APPROVAL	6/15/92	GM

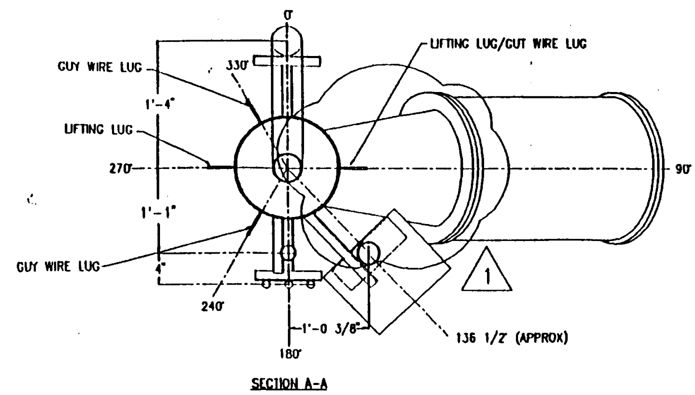
ALLIED FLARE, INC.
P.O. BOX 58294 HOUSTON, TEXAS 77258

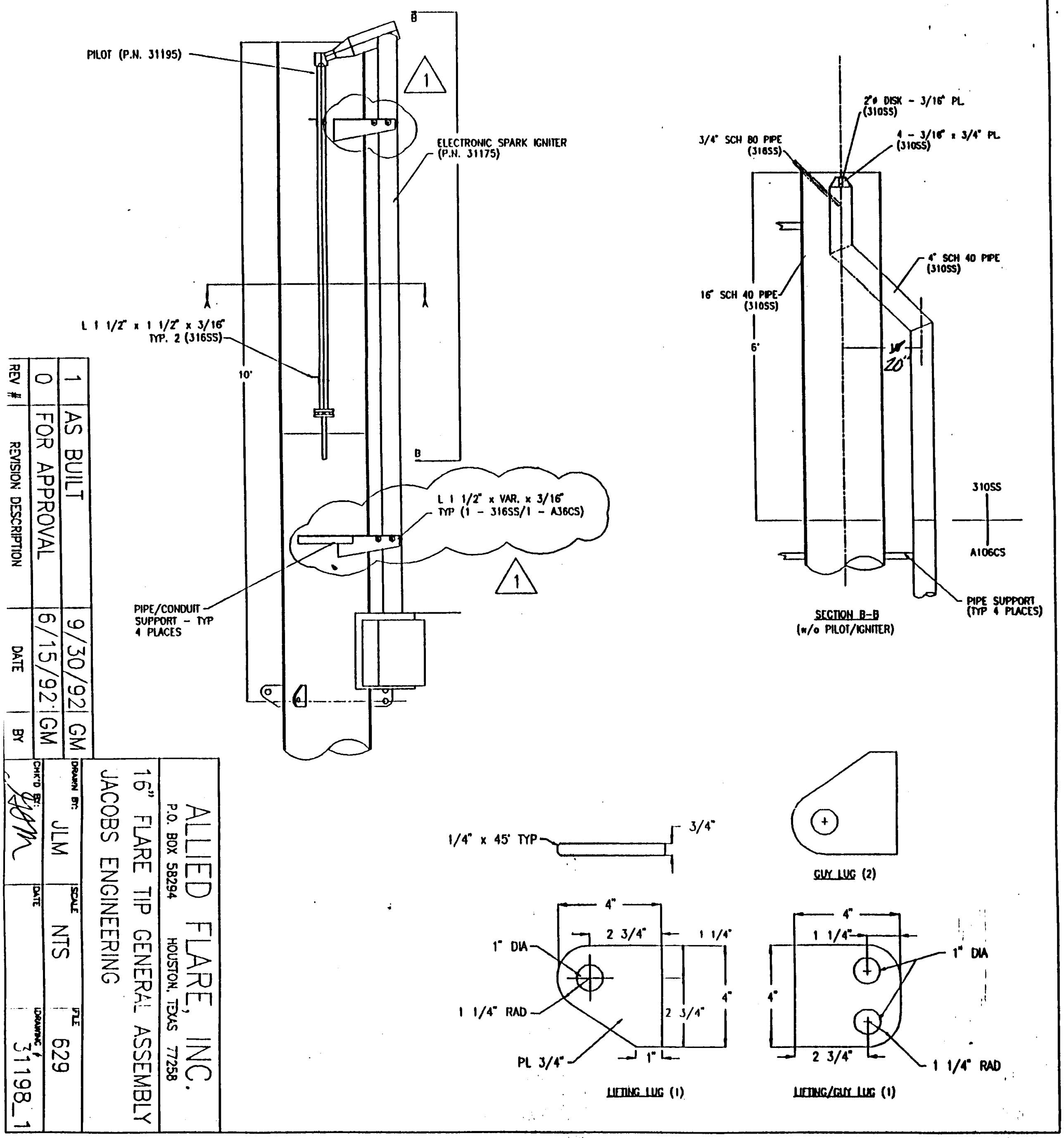
16" GAS ASSIST FLARE TIP
JACOBS ENGINEERING

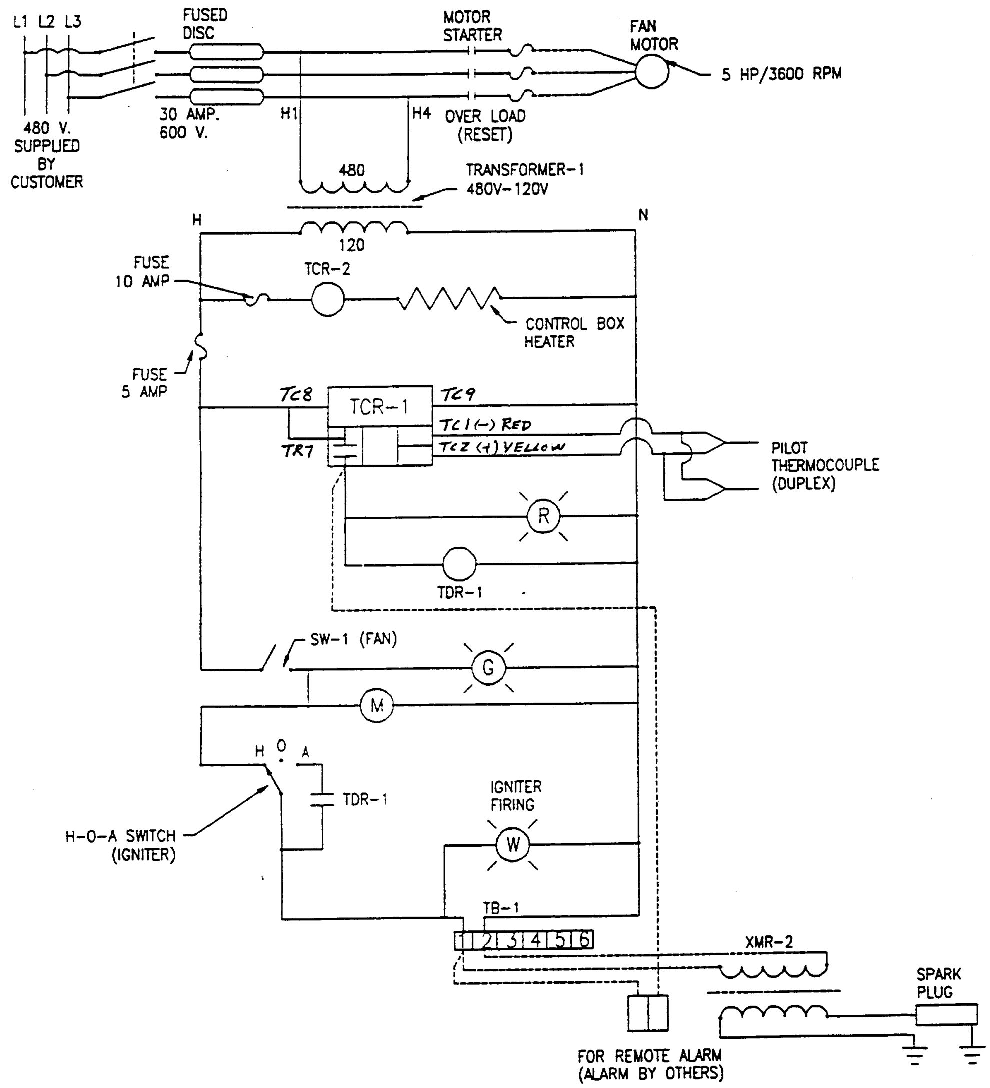
DRAWN BY:	SCALE	FILE
JLM	NTS	E29
CHK'D BY:	DATE	DRAWING #
[signature]	6/15/92	31196_1

NOTE: 1. ASSEMBLE IN 0° UP POSITION;
LIFT FROM 0° UP POSITION

2. TRUE NORTH TO BE DETERMINED/
PROVIDED BY CUSTOMER

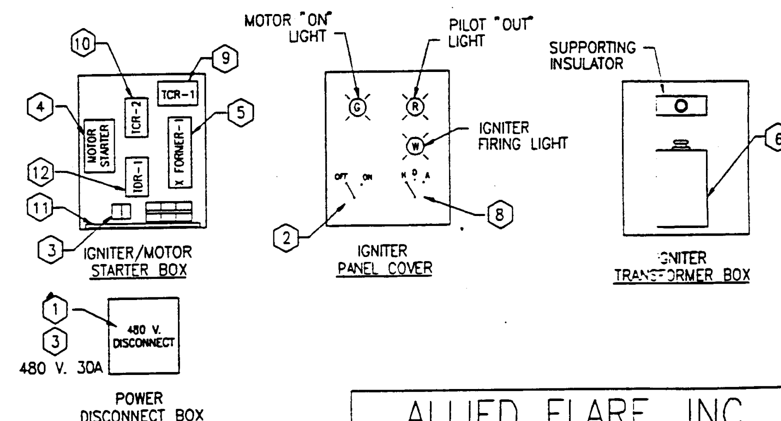






BILL OF MATERIALS

ITEM	DESCRIPTION	QUANTITY
1. 480V DISCONNECT	600V 3Ø FUSED DISCONNECT	1
2. SW-1	ON/OFF FAN SWITCH	1
3. FUSES	480V 30 AMP FUSE 120V 10 AMP FUSE] w/ BLOCKS 120V 5 AMP FUSE	3 1 1
4. STARTER	480V SIZE-0 FAN MOTOR STARTER	1
5. TRANSFORMER-1	480V TO 120V	1
6. TRANSFORMER-2	HIGH-VOLTAGE IGNITER T'FORMER	1
7. INDICATOR LIGHTS	GREEN FAN MOTOR "ON" WHITE IGNITER FIRING RED PILOT "OUT"	1 1 1
8. H-O-A SWITCH	HAND-OFF-AUTOMATIC IGNITER SWITCH	1
9. TCR-1	THERMOCOUPLE RELAY CLOSES ON LOW TEMPERATURE	1
10. TCR-2	TEMP. SWITCH FOR CONTROL BOX	1
11. CONTROL BOX HEATER	120V CHROMALOX HEATER STRIP	1
12. TDR-1	SPARK IGNITER TIME DELAY	1



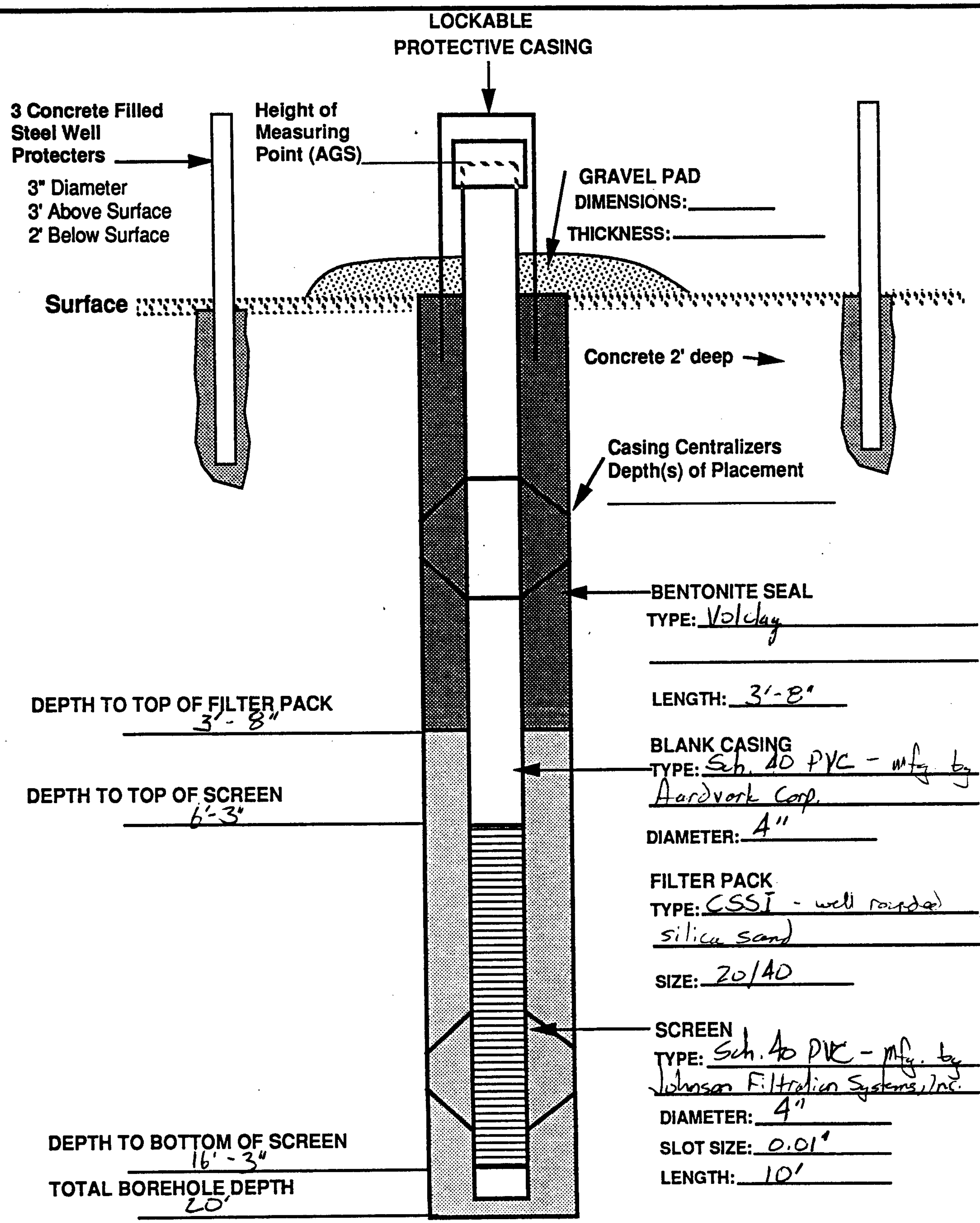
ALLIED FLARE, INC.
P.O. BOX 58294 HOUSTON, TEXAS 77258

ELECTRICAL SYSTEM
JACOBS ENGINEERING

REV #	REVISION DESCRIPTION	DATE	BY
1	AS BUILT	08-17-92	GM
0	FOR APPROVAL	06-15-92	GM

DRAWN BY:	SCALE	FILE
JLM	NTS	629
CHK'D BY:	DATE	DRAWING #
[signature]	10/2/92	31199_1

X



BOREHOLE DIAMETER 10.75" :

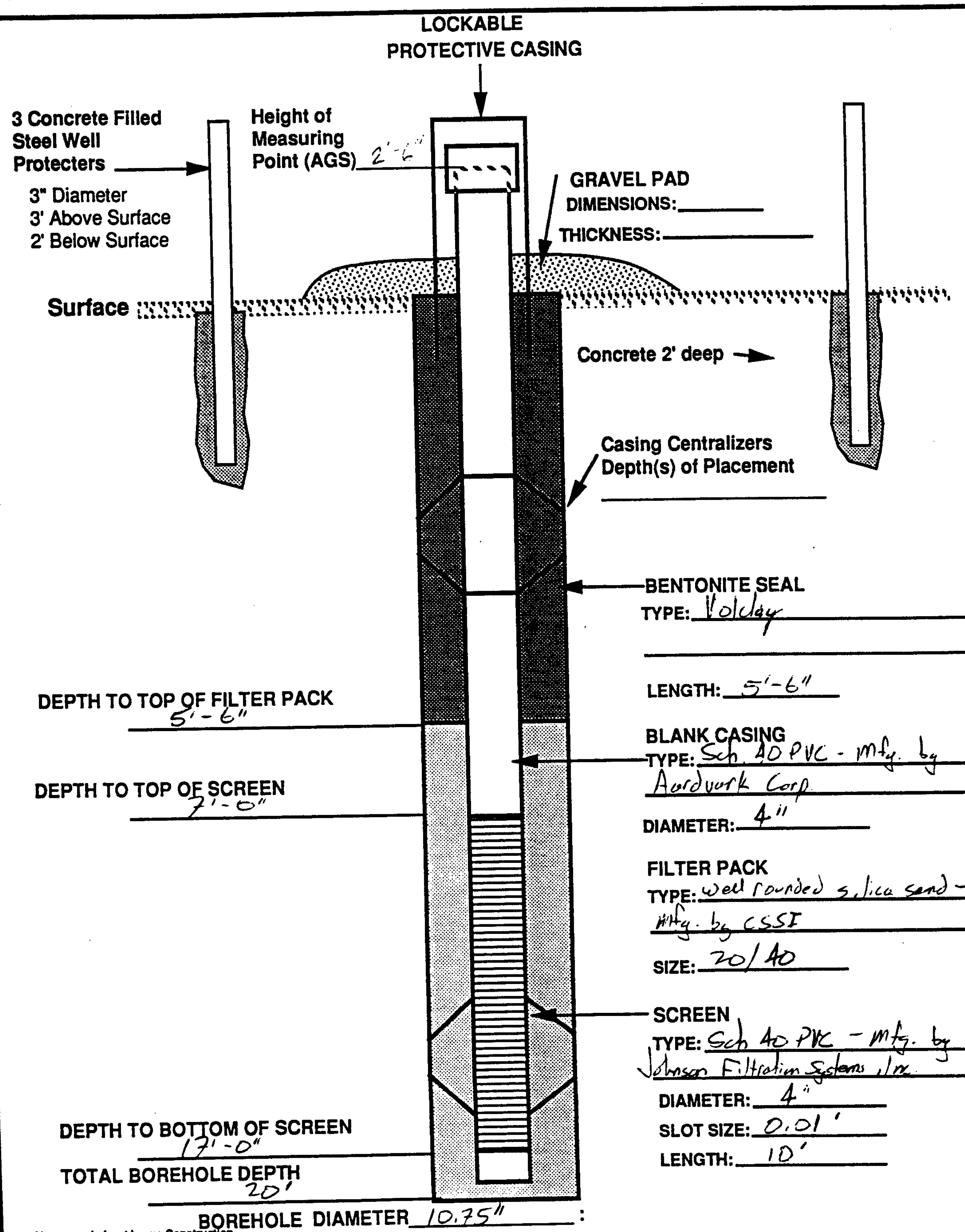
Above grade frost heave Construction

ABOVE GRADE FROST HEAVE MONITORING WELL CONSTRUCTION DETAIL

JE
JACOBS ENGINEERING GROUP

WELL NUMBER VEW-01	DRILLING CONTRACTOR Ambler Exploration Inc.
PROJECT 05G10400 1381	DRILLING METHOD Hollow stem auger
START DATE 13 June 92 STOP DATE 14 June 92	DRILL RIG AND SIZE Mobil B61
FIELD TECH REPRESENTATIVE Garove / Brown	DRILLER Steve Woodstock

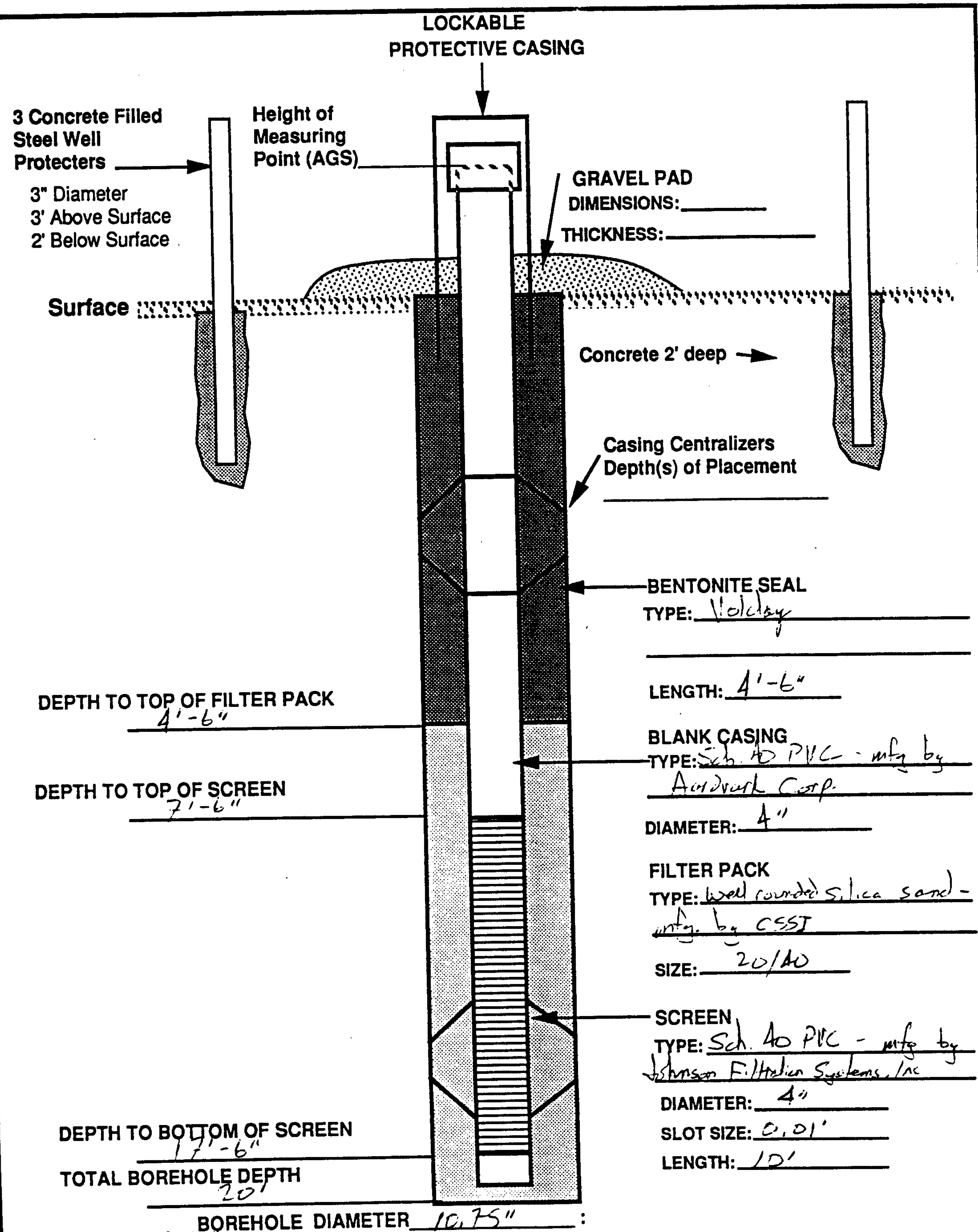
X



ABOVE GRADE FROST HEAVE MONITORING WELL CONSTRUCTION DETAIL

JE JACOBS ENGINEERING GROUP	WELL NUMBER VEW-02	DRILLING CONTRACTOR Ambler Exploration, Inc.
	PROJECT 05610400 1381	DRILLING METHOD Hollow stem auger
	START DATE 14 Jun 92 STOP DATE 14 Jun 92	DRILL RIG AND SIZE Mobil B61
	FIELD TECH REPRESENTIVE Gordon Brown	DRILLER Steve Woodstock

X

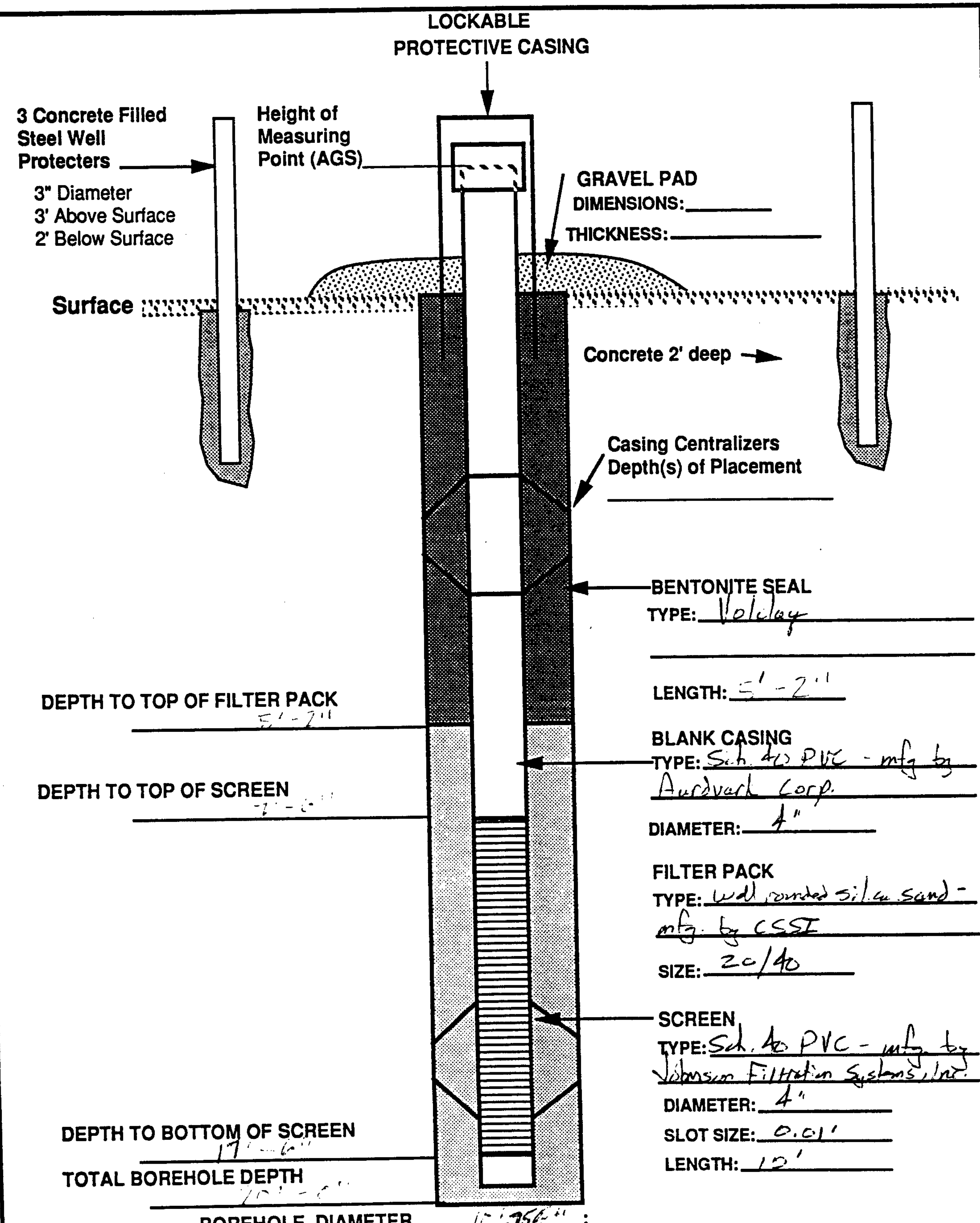


ABOVE GRADE FROST HEAVE MONITORING WELL CONSTRUCTION DETAIL

JE
JACOBS ENGINEERING GROUP

WELL NUMBER VEW-03
PROJECT 05G10A00 1381
START DATE 15 June 92 STOP DATE 15 June 92
FIELD TECH REPRESENTIVE Gordie/Brown

DRILLING CONTRACTOR Antler Exploration, Inc
DRILLING METHOD hollow stem auger
DRILL RIG AND SIZE Mobil B61
DRILLER Steve Woodstock



Above grade frost heave Construction

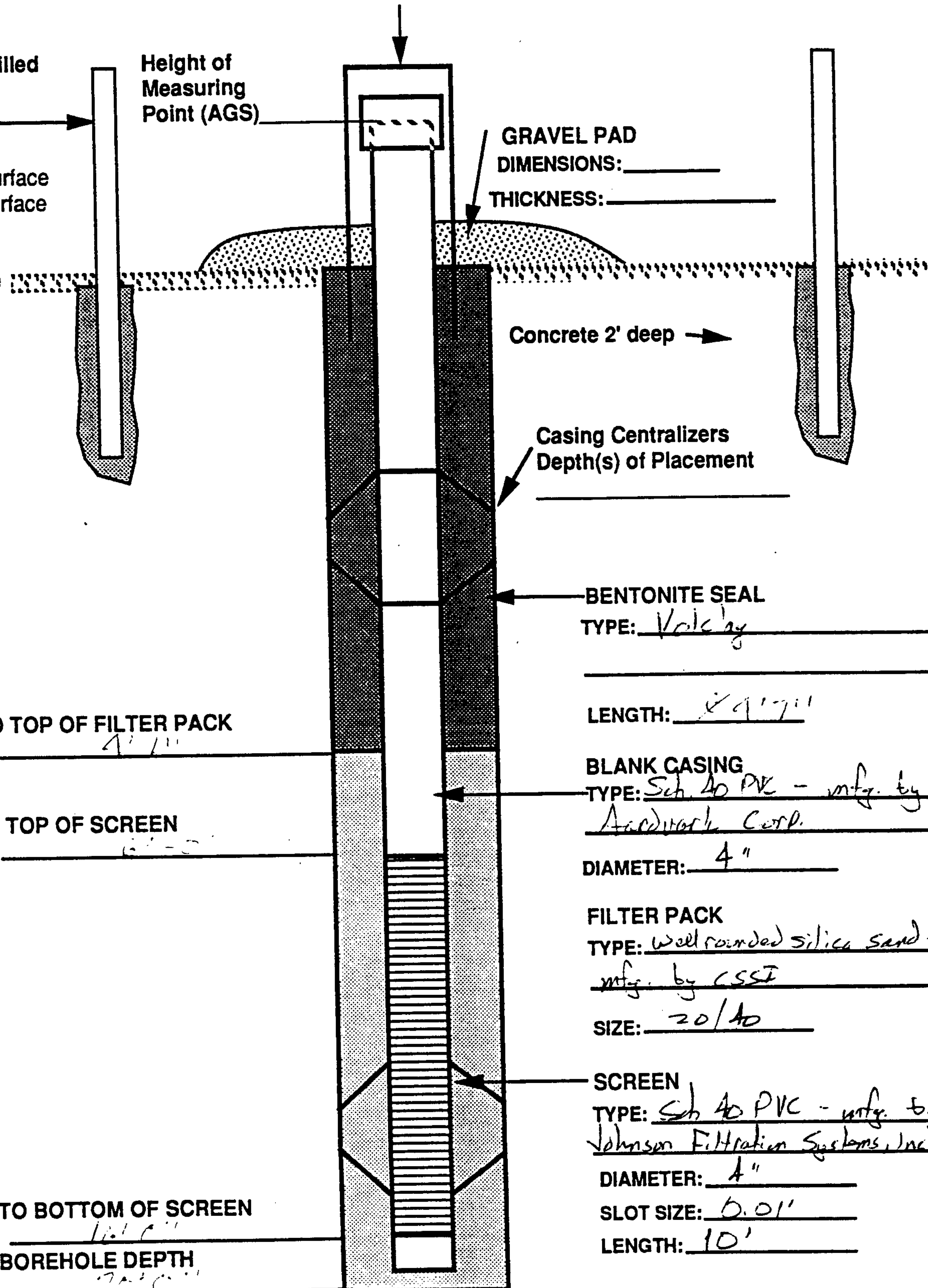
ABOVE GRADE FROST HEAVE MONITORING WELL CONSTRUCTION DETAIL

JE
JACOBS ENGINEERING GROUP

WELL NUMBER VEW-04
PROJECT 05610400
START DATE 15 June 92 STOP DATE 15 June 92
FIELD TECH REPRESENTATIVE Garrone / Brown

DRILLING CONTRACTOR Tinsler Exploration, Inc.
DRILLING METHOD Hollow stem auger
DRILL RIG AND SIZE Mobil B61
DRILLER Steve Woodstock

X



GRAVEL PAD
DIMENSIONS: ______
THICKNESS: ______

Casing Centralizers Depth(s) of Placement ______

BENTONITE SEAL
TYPE: Volclay
LENGTH: [illegible]

DEPTH TO TOP OF FILTER PACK 4' 1"

BLANK CASING
TYPE: Sch. 40 PVC - mfg. by Aardvark Corp.
DIAMETER: 4"

DEPTH TO TOP OF SCREEN [illegible]

FILTER PACK
TYPE: Well rounded silica sand - mfg. by CSSI
SIZE: 20/40

SCREEN
TYPE: Sch 40 PVC - mfg. by Johnson Filtration Systems, Inc.
DIAMETER: 4"
SLOT SIZE: 0.01'
LENGTH: 10'

DEPTH TO BOTTOM OF SCREEN [illegible]

TOTAL BOREHOLE DEPTH [illegible]

BORHOLE DIAMETER [illegible] :

Above grade frost heave Construction

JE JACOBS ENGINEERING GROUP	**ABOVE GRADE FROST HEAVE MONITORING WELL CONSTRUCTION DETAIL** WELL NUMBER VEW-05 — DRILLING CONTRACTOR Amber Exploration, Inc. PROJECT 05G10400 1381 — DRILLING METHOD Hollow stem auger START DATE 16 Jun 92 STOP DATE 16 Jun 92 — DRILL RIG AND SIZE Mobil B61 FIELD TECH REPRESENTIVE Goode / Brown — DRILLER Steve Woodstock

X

LOCKABLE PROTECTIVE CASING

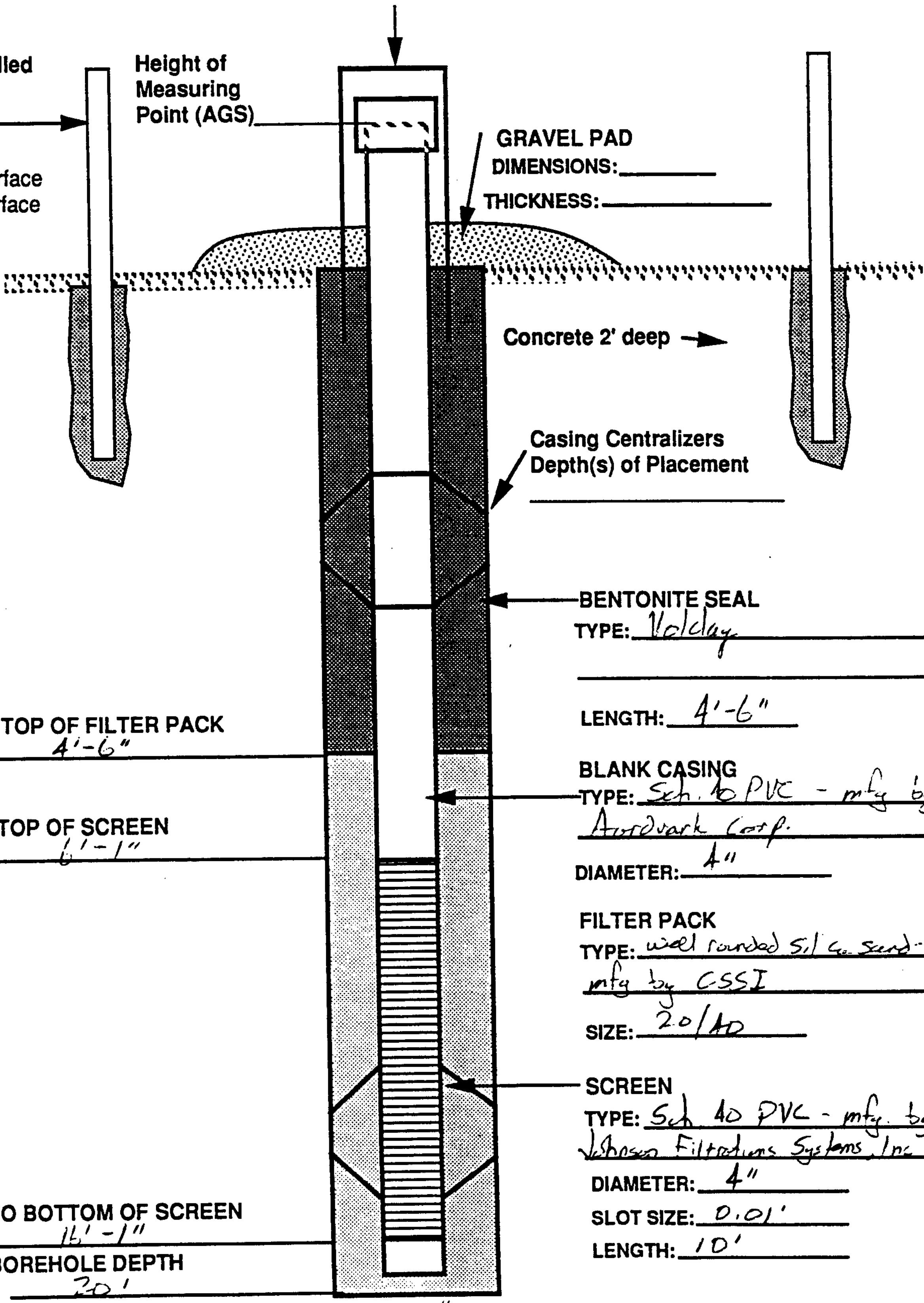
3 Concrete Filled Steel Well Protecters
3" Diameter
3' Above Surface
2' Below Surface

Height of Measuring Point (AGS)

GRAVEL PAD
DIMENSIONS: ______
THICKNESS: ______

Surface

Concrete 2' deep



Casing Centralizers Depth(s) of Placement ______

BENTONITE SEAL
TYPE: Volclay
LENGTH: 4'-6"

BLANK CASING
TYPE: Sch. 40 PVC - mfg by Aardvark Corp.
DIAMETER: 4"

FILTER PACK
TYPE: well rounded Sil Co. sand - mfg by CSSI
SIZE: 20/40

SCREEN
TYPE: Sch 40 PVC - mfg. by Johnson Filtrations Systems, Inc
DIAMETER: 4"
SLOT SIZE: 0.01'
LENGTH: 10'

DEPTH TO TOP OF FILTER PACK 4'-6"

DEPTH TO TOP OF SCREEN 6'-1"

DEPTH TO BOTTOM OF SCREEN 16'-1"

TOTAL BOREHOLE DEPTH 20'

BOREHOLE DIAMETER 10.75" :

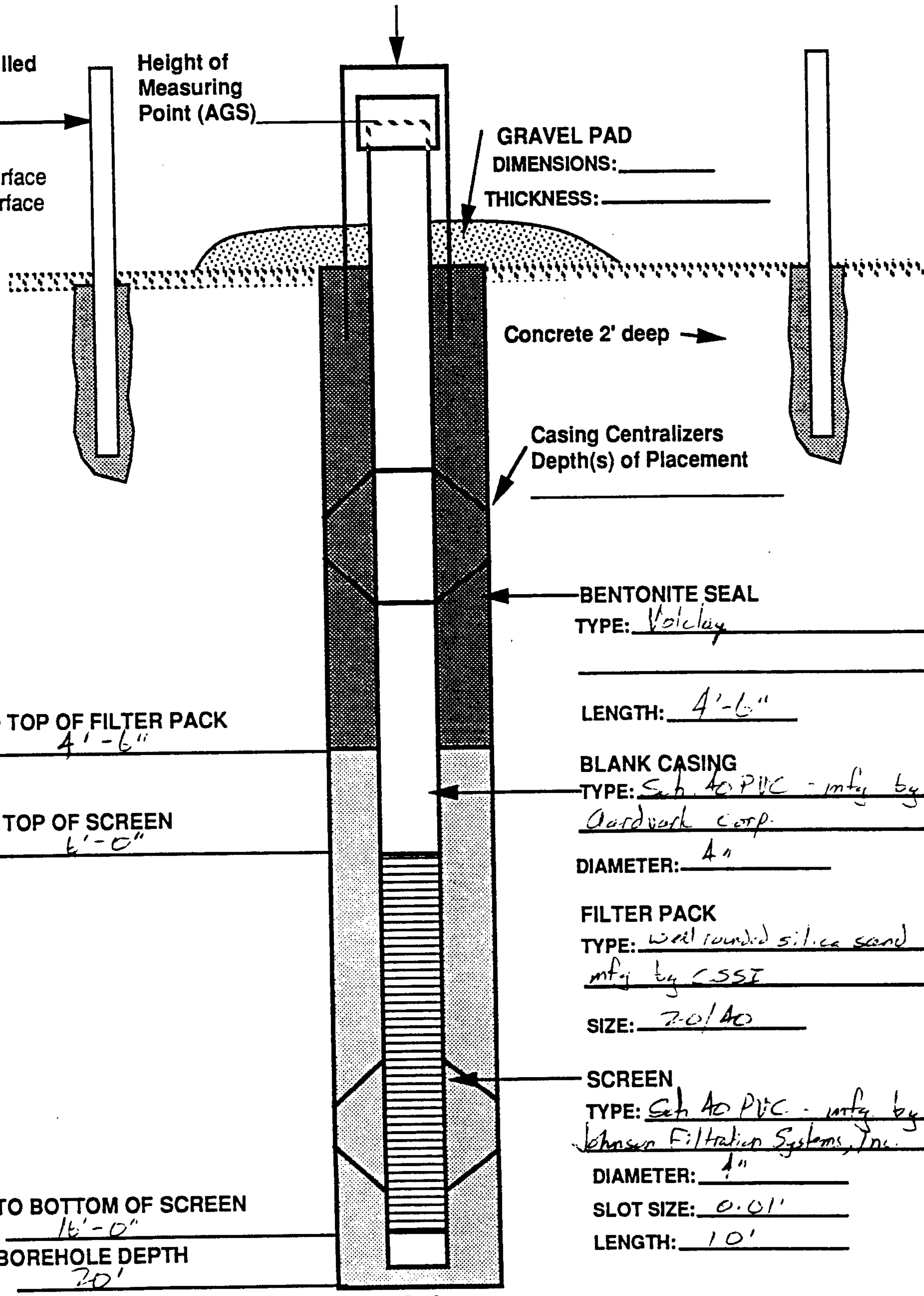
Above grade frost heave Construction

ABOVE GRADE FROST HEAVE MONITORING WELL CONSTRUCTION DETAIL

JE
JACOBS ENGINEERING GROUP

WELL NUMBER VEW-06
PROJECT 05610400 1381
START DATE 17 June 92 STOP DATE 17 June 92
FIELD TECH REPRESENTIVE Gordie Brown

DRILLING CONTRACTOR Amsler Exploration, Inc
DRILLING METHOD Hollow stem auger
DRILL RIG AND SIZE Mobil B61
DRILLER Steve Woodstock



X

GRAVEL PAD
DIMENSIONS: ______
THICKNESS: ______

Casing Centralizers Depth(s) of Placement ______

BENTONITE SEAL
TYPE: Volclay
LENGTH: 4'-6"

BLANK CASING
TYPE: Sch. 40 PVC - mfg by Aardvark Corp.
DIAMETER: 4"

FILTER PACK
TYPE: well rounded silica sand mfg by CSSI
SIZE: 20/40

SCREEN
TYPE: Sch 40 PVC - mfg by Johnson Filtration Systems, Inc.
DIAMETER: 4"
SLOT SIZE: 0.01'
LENGTH: 10'

DEPTH TO TOP OF FILTER PACK 4'-6"

DEPTH TO TOP OF SCREEN 6'-0"

DEPTH TO BOTTOM OF SCREEN 16'-0"

TOTAL BOREHOLE DEPTH 20'

BOREHOLE DIAMETER 10.75" :

Above grade frost heave Construction

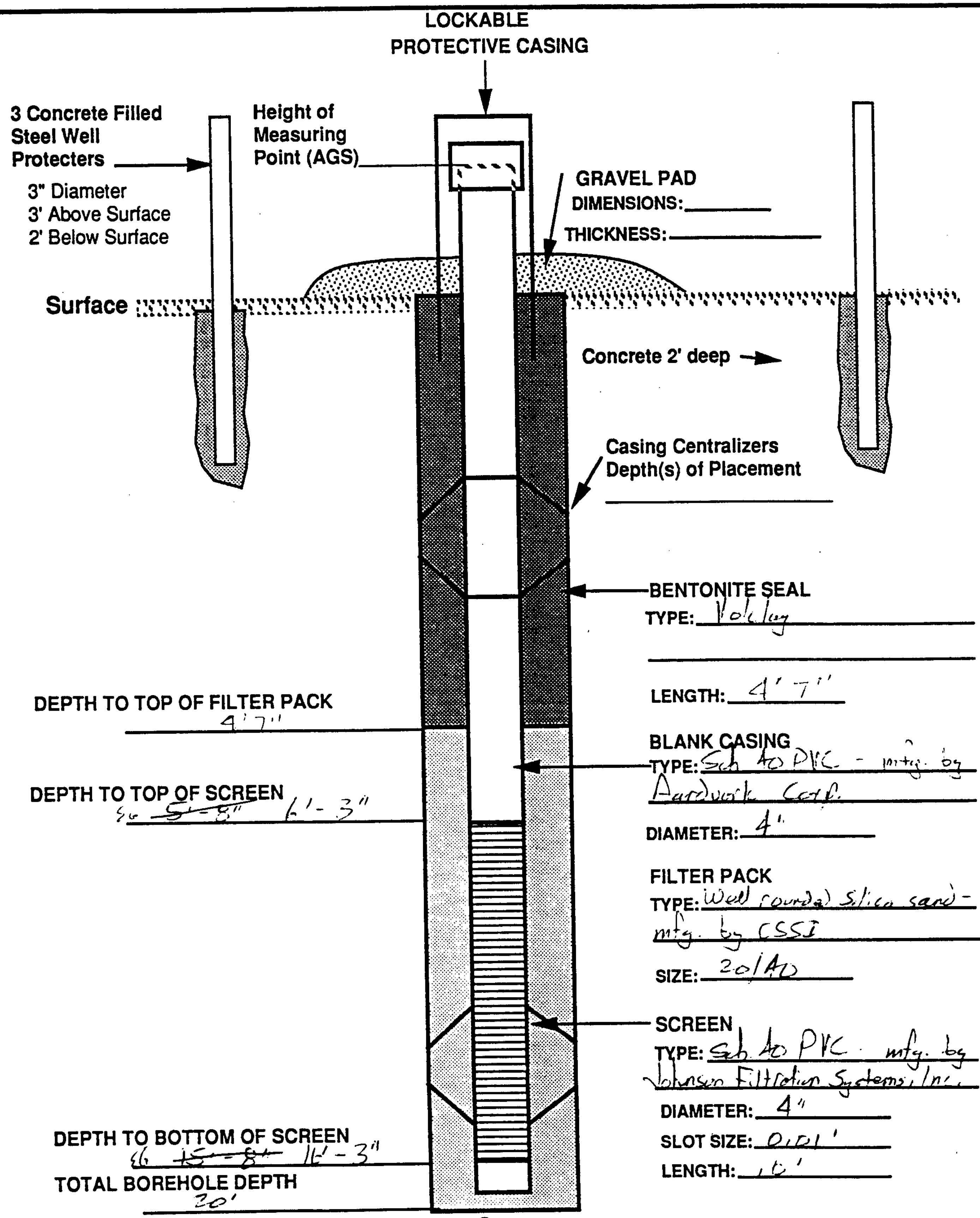
ABOVE GRADE FROST HEAVE MONITORING WELL CONSTRUCTION DETAIL

JE
JACOBS ENGINEERING GROUP

WELL NUMBER VEW - 07
PROJECT 05G10400 1381
START DATE 17 Jun 92 STOP DATE 17 Jun 92
FIELD TECH REPRESENTIVE Gorche / Brown

DRILLING CONTRACTOR Ambler Exploration
DRILLING METHOD Hollow stem auger
DRILL RIG AND SIZE Mobil B61
DRILLER Steve Woodstock

X



BOREHOLE DIAMETER 10.75" :

Above grade frost heave Construction

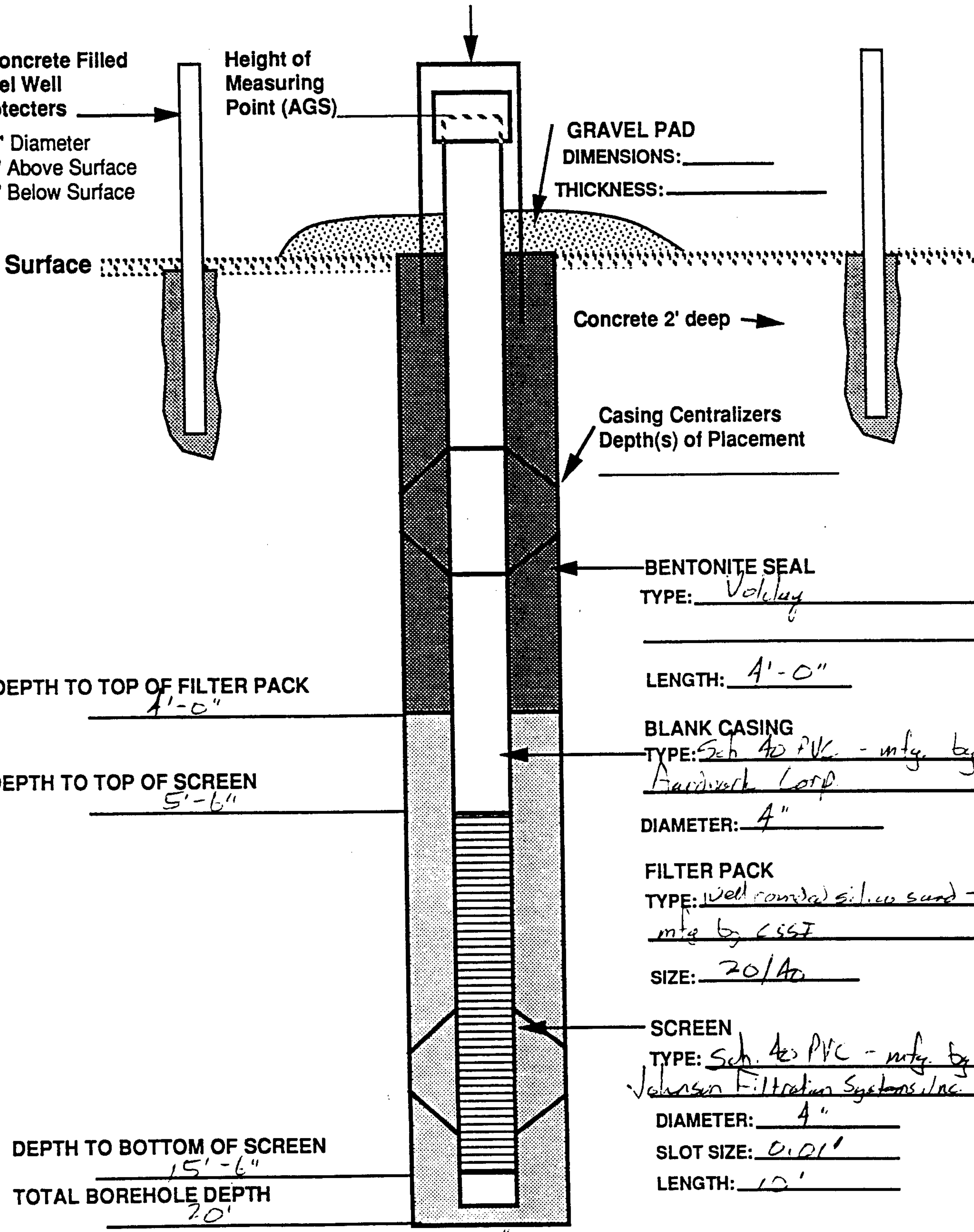
ABOVE GRADE FROST HEAVE MONITORING WELL CONSTRUCTION DETAIL

JE
JACOBS ENGINEERING GROUP

WELL NUMBER VEW-08
PROJECT USG10400
START DATE 18 June 92 STOP DATE 18 June 92
FIELD TECH REPRESENTIVE Gotone / Brown

DRILLING CONTRACTOR Ambler Exploration Inc
DRILLING METHOD Hollow stem auger
DRILL RIG AND SIZE Mobil B61
DRILLER Steve Woodstock

X



GRAVEL PAD
DIMENSIONS: ______
THICKNESS: ______

Casing Centralizers Depth(s) of Placement ______

BENTONITE SEAL
TYPE: Volclay
LENGTH: 4'-0"

DEPTH TO TOP OF FILTER PACK 4'-0"

BLANK CASING
TYPE: Sch 40 PVC - mfg. by Aardvark Corp.
DIAMETER: 4"

DEPTH TO TOP OF SCREEN 5'-6"

FILTER PACK
TYPE: Well rounded silica sand - mfg by CSSI
SIZE: 20/40

SCREEN
TYPE: Sch. 40 PVC - mfg. by Johnson Filtration Systems, Inc.
DIAMETER: 4"
SLOT SIZE: 0.01'
LENGTH: 10'

DEPTH TO BOTTOM OF SCREEN 15'-6"

TOTAL BOREHOLE DEPTH 20'

BOREHOLE DIAMETER 10.75" :

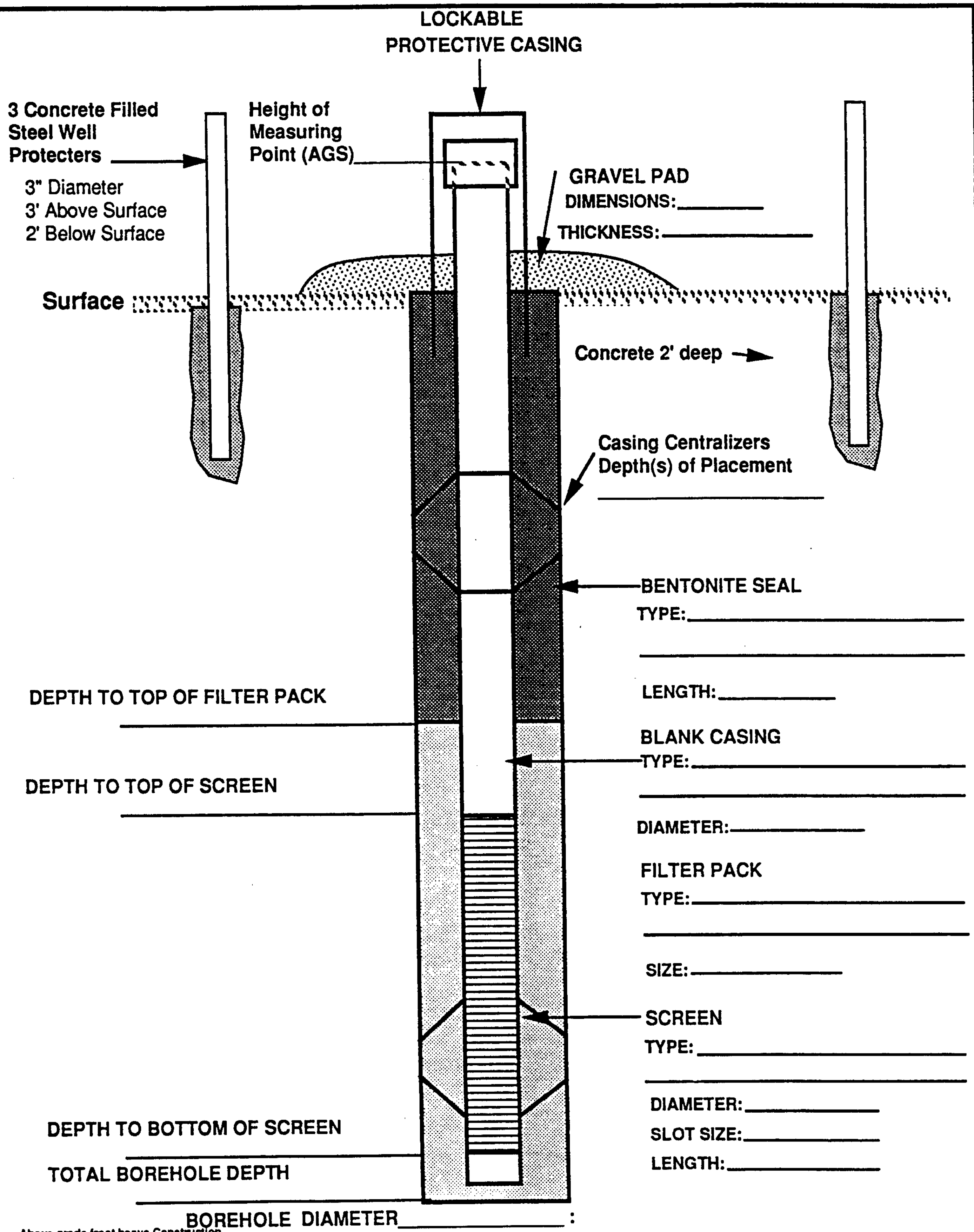
Above grade frost heave Construction

ABOVE GRADE FROST HEAVE MONITORING WELL CONSTRUCTION DETAIL

JE
JACOBS ENGINEERING GROUP

WELL NUMBER VEW-09
PROJECT 05G10400 B81
START DATE 18 Jun 92 STOP DATE 18 Jun 92
FIELD TECH REPRESENTIVE Gorove / Brown
DRILLING CONTRACTOR Ambler Exploration, Inc
DRILLING METHOD Hollow stem auger
DRILL RIG AND SIZE Mobil B61
DRILLER Steve Woodstock

X



ABOVE GRADE FROST HEAVE MONITORING WELL CONSTRUCTION DETAIL

JE
JACOBS
ENGINEERING
GROUP

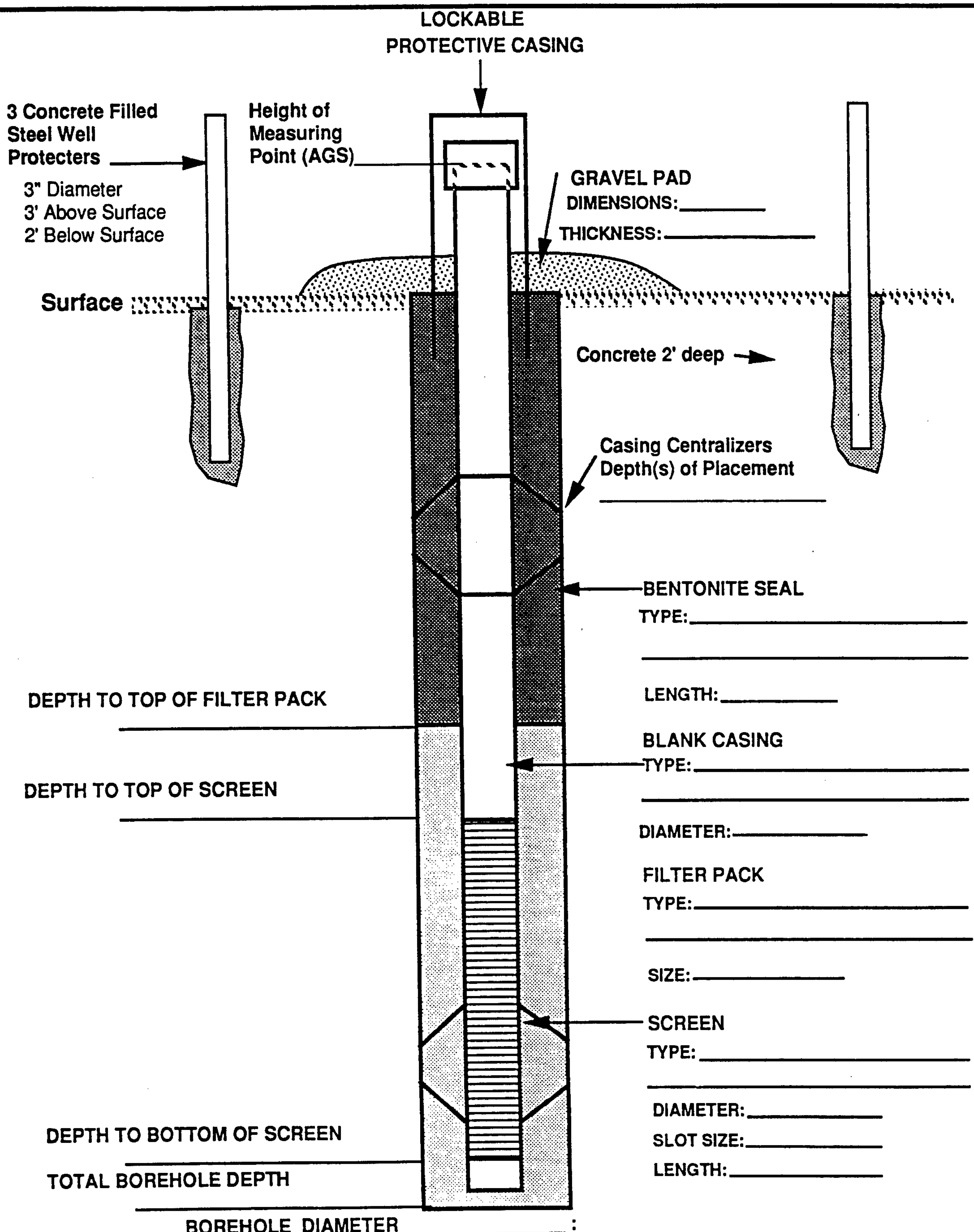
WELL NUMBER ____________________ DRILLING CONTRACTOR ____________________

PROJECT ____________________ DRILLING METHOD ____________________

START DATE __________ STOP DATE __________ DRILL RIG AND SIZE ____________________

FIELD TECH REPRESENTIVE ____________________ DRILLER ____________________

X



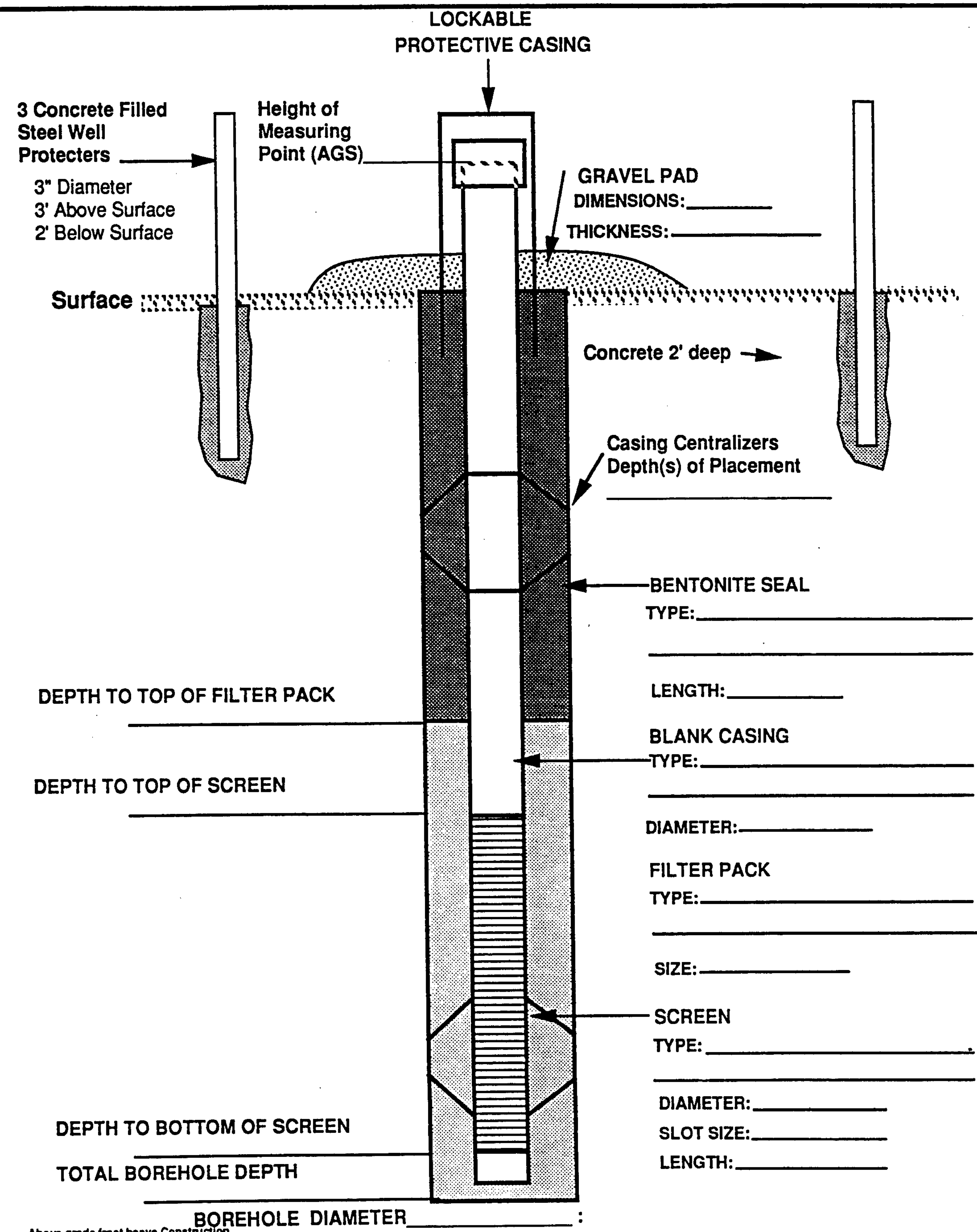
JE

JACOBS ENGINEERING GROUP

ABOVE GRADE FROST HEAVE MONITORING WELL CONSTRUCTION DETAIL

WELL NUMBER ______	DRILLING CONTRACTOR ______
PROJECT ______	DRILLING METHOD ______
START DATE ______ STOP DATE ______	DRILL RIG AND SIZE ______
FIELD TECH REPRESENTIVE ______	DRILLER ______

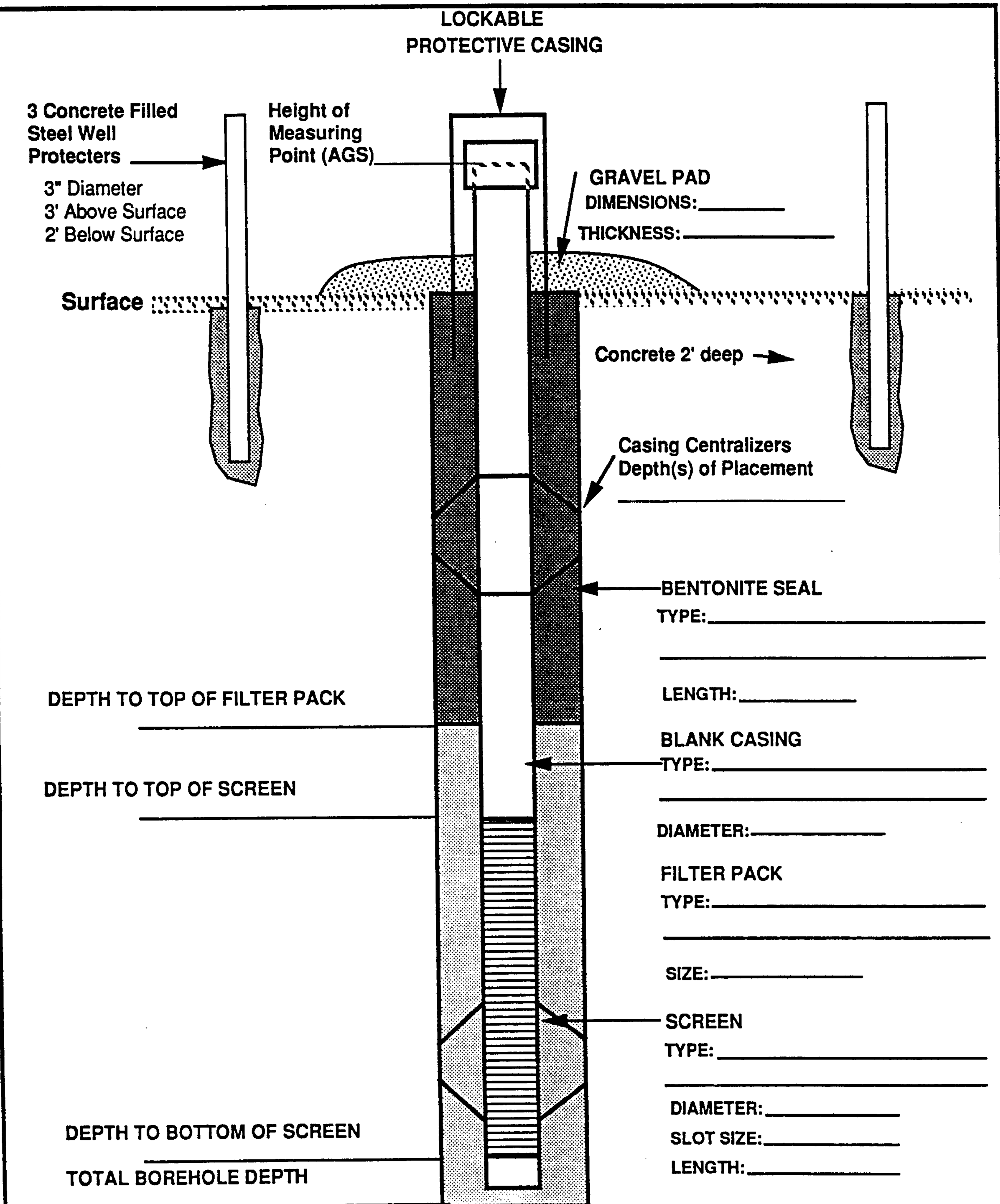
X



ABOVE GRADE FROST HEAVE MONITORING WELL CONSTRUCTION DETAIL

JE JACOBS ENGINEERING GROUP	WELL NUMBER ______	DRILLING CONTRACTOR ______
	PROJECT ______	DRILLING METHOD ______
	START DATE ______ STOP DATE ______	DRILL RIG AND SIZE ______
	FIELD TECH REPRESENTIVE ______	DRILLER ______

X



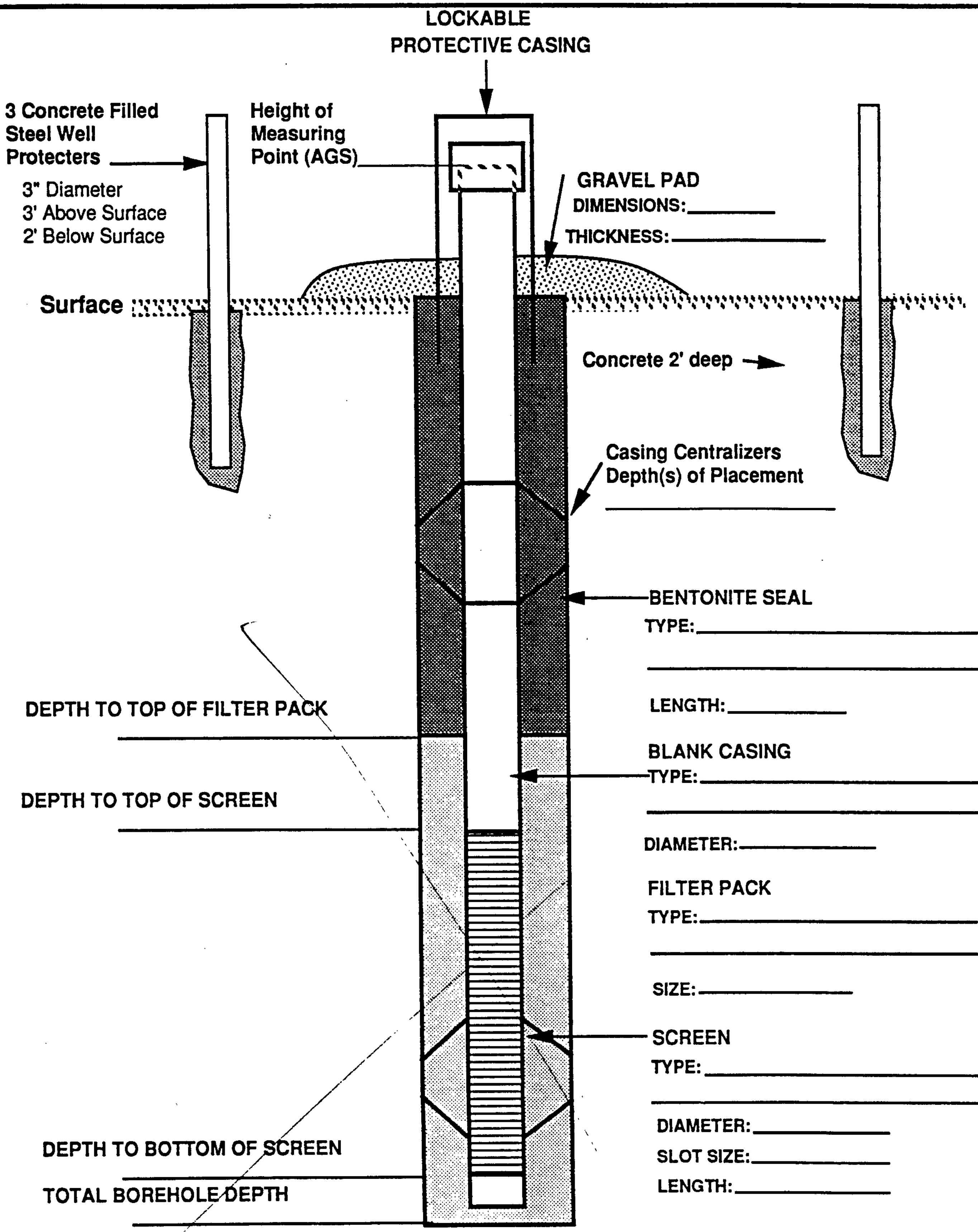
BOREHOLE DIAMETER______________ :

Above grade frost heave Construction

ABOVE GRADE FROST HEAVE MONITORING WELL CONSTRUCTION DETAIL

JE JACOBS ENGINEERING GROUP	WELL NUMBER__________ PROJECT __________ START DATE______ STOP DATE______ FIELD TECH REPRESENTIVE__________	DRILLING CONTRACTOR__________ DRILLING METHOD __________ DRILL RIG AND SIZE __________ DRILLER __________

X

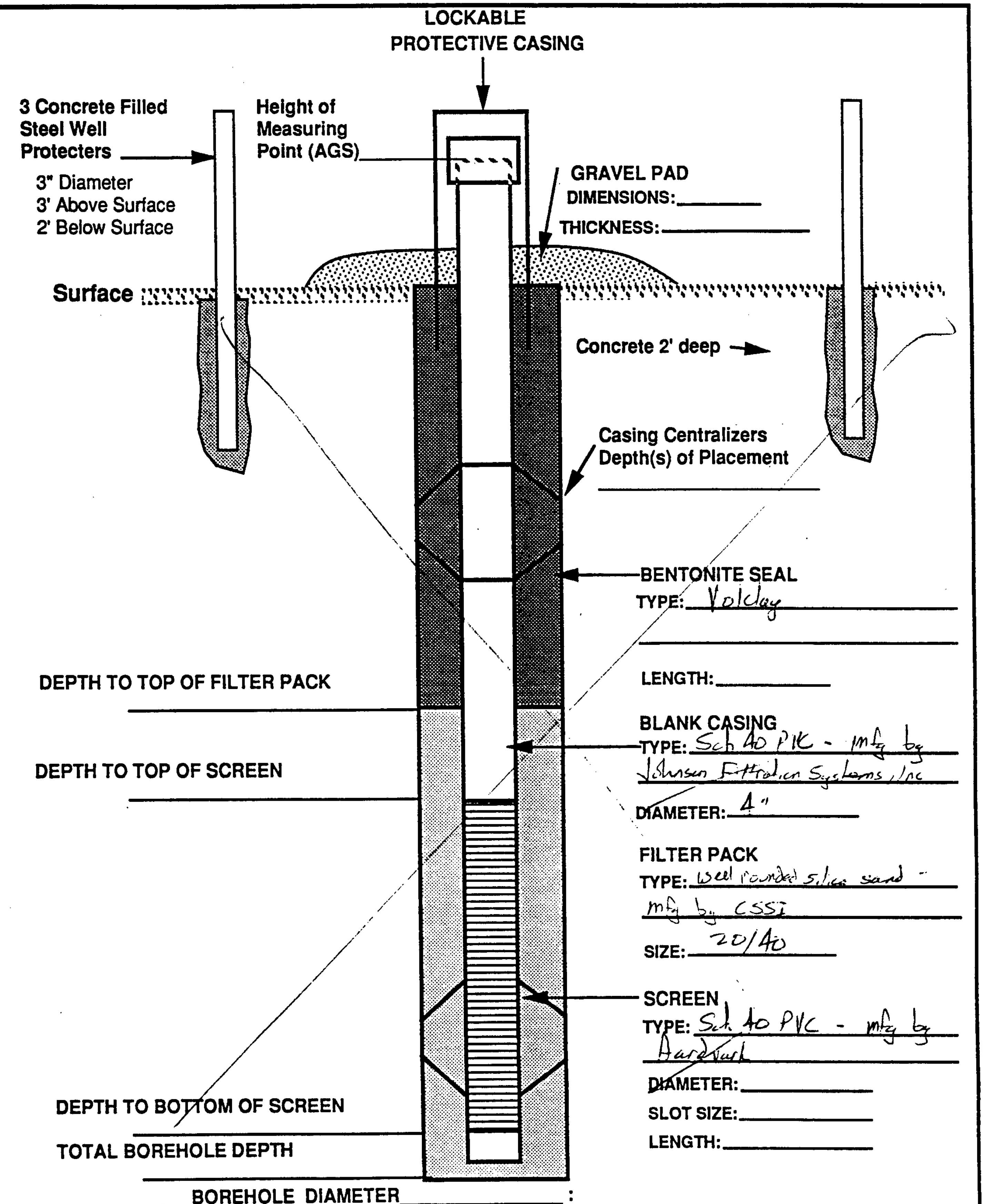


BOREHOLE DIAMETER ____________ :

Above grade frost heave Construction

JE JACOBS ENGINEERING GROUP	**ABOVE GRADE FROST HEAVE MONITORING WELL CONSTRUCTION DETAIL** WELL NUMBER ~~BSG-104~~ PROJECT ____________ START DATE ________ STOP DATE ________ FIELD TECH REPRESENTIVE ____________	DRILLING CONTRACTOR ____________ DRILLING METHOD ____________ DRILL RIG AND SIZE ____________ DRILLER ____________

X



Above grade frost heave Construction

JE JACOBS ENGINEERING GROUP	ABOVE GRADE FROST HEAVE MONITORING WELL CONSTRUCTION DETAIL	
	WELL NUMBER VEW-03	DRILLING CONTRACTOR Ambler Exploration, Inc.
	PROJECT 05G10400 1381	DRILLING METHOD Hollow stem auger
	START DATE 15 June 92 STOP DATE 15 June 92	DRILL RIG AND SIZE Mobil B61
	FIELD TECH REPRESENTIVE Gorove / Brown	DRILLER Steve Woodstock

DESIGN SPECIFICATIONS

ITEM	DESCRIPTION	QUANTITY
1)	PUMP ASSEMBLY	1

A) <u>Liquid Ring Vacuum Pump</u> [02.001] The vacuum pump shall be single stage, single lobe, positive displacement non-pulsating, liquid ring type with enclosed modular body constructed of cast iron. The vacuum pump shall have a 5-year warranty.

Pump capacity:	500 SCFM at 15 inches Hg
Maximum BHP:	75
Maximum vacuum:	25 inches Hg
Pump materials:	cast iron casing, ductile iron impellers, AISI 420 s/steel shaft
Shaft sealing:	carbon face mechanical seal

Discharge side of the vacuum pump will be equipped with a Knunkle Model #337-3 pressure relief valve set for 3 PSIG. The discharge from the pressure relief valve should be piped back into the knockout tank, thus preventing a discharge of untreated vapor into the atmosphere.

Vacuum pump unit will be equipped with a vacuum breaker (Knunkle Model #215 V size 2 1/2 inch set for 25 inches Hg on line between knockout tank and vacuum pump.

The shaft bearing shall be grease lubricated self-aligning anti-friction bearings with minimum L-10 life rating of 50,000 hours in accordance with AFBMA. Bearings must be able to take the loads due to dead weight, unbalance, belt load and thrust of rotor assembly. Grease lubrication fittings shall be standard hydraulic type. Bearings shall be adequately lubricated to protect against corrosion during shipment. Bearings shall be rated for 24 hour continuous duty.

B) <u>Electric Motor</u> — 1

75 HP, 1,800 RPM, 460 volts, 3 phase encl. X.P. Class 1 Group D

C) <u>Coupling and Guard for Direct Drive</u> — 1

D) <u>Inlet Vacuum Gauge</u> — 1

E) <u>Inlet Check Valve</u> Compatible with vacuum inlet — 1

DESIGN SPECIFICATIONS

ITEM	DESCRIPTION		QUANTITY
2)	A) Knockout Tank [13.001] Rated at full vacuum (29.9 inches Hg).		1
	Volume:	490 gallons	
	Size (approx:)	36 inches diameter, 106 inches length between seams	
	Material:	1/4 inch steel	
	Bleed valve:	2 inch located above enclosure	
	Inlet:	6 inch with shut-off valve	
	Inlet downturn:	the 6 inch inlet will extend 18 inches into tank with a 1 foot downturn (90 degree)	
	Outlet size:	compatible with vacuum pump inlet	
	Outlet upturn:	the outlet will extend 12 to 18 inches into tank with a 1 foot upturn (90 degrees)	
	Liquid outlet:	outlet pipe in bottom of tank	
	B) Oil Water Drain Pump [01.001]		1
	Size:	3/4 HP, 460 volts, 3 phase, enclosed X.P. Class 1 Group D	
	Capacity:	30 gallons per minute	
	Level control:	explosion proof controls, pump and level switch wired and mounted high level emergency shut-down wired and mounted	
3)	A) Sealing Liquid Separator Tank [13.002] The separator tank shall have an external drain loop, tangential flanged inlet and flanged top vent connections. Seal water piping shall be SCH 40 carbon steel with screwed fittings		1
	Diameter:	26 inches	
	Height:	48 inches	
	Material:	1/4 inch steel	
	Exit pipe size:	6 inch	
	Gauge:	pressure gauge installed in exit pipe before installed exit pipe flange	
	B) Seal Water Circulating Pump [01.002]		1
	Size:	1/2 HP, 460 volts, 3 phase, enclosed X.P. Class 1 Group D	

DESIGN SPECIFICATIONS

ITEM	DESCRIPTION		QUANTITY
	B) <u>Seal Water Circulating Pump</u> [01.002]		1
	Size:	1/2 HP, 460 volts, 3 phase, enclosed X.P. Class 1 Group D	
	C) <u>Return Line Strainer</u> [22.001]		1
	Size:	10 micron in-line filter cartridge	
	D) <u>Return Water Regulating Valve and Shut-Off Valve</u>		1
	Size:	compatible with circulation pump	
	E) <u>Temperature Gauge</u>		1
	Range:	compatible with operation of pump wired and mounted to control heat exchanger	
	F) <u>Heat Exchanger</u> [11.001]		1
	Type:	water to air	
	Fan:	460 volts, 60 Hz, 3 phase, explosion proof	
	Control:	seal water temperature and enclosure interior air temperature wired and mounted (see thermostatic controls)	
	Shutters:	hot air from the heat exchanger fan will exit the enclosure through a set of shutters thermostatic controlled	
	G) <u>Flame Arrestor</u> [36.001]		1
	Protectoseal C25006 (six inch pipe size) bidirectional detonation flame arrester (or equal) with 3/4 inch NPT optional fitting for temperature probe		
	H) <u>High Water Level Discharge</u>		1
	A high water level discharge to the outside of the enclosure will be provided. The high water level should be approximately 2 inches above the center line of the pump shaft. The level measurement could be a float type device		

DESIGN SPECIFICATIONS

ITEM	DESCRIPTION	QUANTITY
	I) Low Water Level -Make Up Water Tank [09.002]	1

A low water level inlet connection approximately at the center line of the vacuum pump shall be provided. A 15 gallon make-up water tank should be mounted on the side of the separator tank at the top and piped to the low water connection. The inlet to the make-up water tank should extend above the enclosure roof for filling purposes.

4)	ELECTRICAL CONTROLS	1

A) Electrical Controls Panel mounted and wired on the outside of enclosure NEMA 7 explosion proof.

B) Items to be Mounted and Wired in the Control Panel

- power supply connection - 460 volts, 3 phase, 60 Hz
- full voltage magnetic starter complete with 3-phase overload protection and reset switches
- 110 volt control circuit transformer with fused primary and secondary
- running lights
- stop/start button
- terminal strip for external connections
- 1 high pressure emergency shut-down light
- 1 high water level emergency shut-down light
- 1 flame arrestor back pressure emergency shut-down light

5)	OIL/WATER SEPARATOR	1

A) Highland Tank & Mfg. Co. Model HTL-30 (or equal) [09.001] Parallel corrugated plate gravity displacement separator shall be 5 feet 4 inches long, 1.5 feet wide, 3 feet high, influent rate of 30 gpm.

Effluent characteristics: free petroleum hydrocarbon concentration shall not exceed 15 mg/l

DESIGN SPECIFICATIONS

ITEM	DESCRIPTION	QUANTITY

All interconnecting piping between liquid pump at knockout tank and oil/water separator shall be provided. The interconnecting piping shall be 3 inch C.S. The optional level sensor and oil pump-out pipe is not required. The outlet diameter of the oil skimmer is 3 inches. A 3-inch outlet pipe extending beyond the enclosure wall and reducing to a 1 inch valve shall be provided. The oil/water vent shall extend 1 foot above the enclosure top with a goose neck.

6) SYSTEM ENCLOSURE 1

A) <u>System Enclosure</u> Complete unit except for top half of knockout tank shall be housed in a weather proof enclosure with a Markel Model #XL316-480360-10.0 34150 BTU explosion proof heater unit (UL listings Class 1, Group D, Divisions 1 & 2). The explosion proof heater shall be controlled by an explosion proof thermostat wired and mounted in enclosure.

The enclosure shall be in three compartments for ease of transportation. The knockout tank compartment is approximately 5 feet long by 4 feet wide by 6 feet high. The vacuum pump, motor, separator tank compartment is approximately 9 feet long by 4 feet wide by 6 feet high. The oil/water separator compartment is approximately 7 feet long by 3 feet wide by 6 feet high. The floor shall be 6-inch I-beam frame with 1/4 inch steel plate floor. All walls shall be removable panels made of fiberglass. All walls shall be insulted with fiberglass with fireproof backing (R-13 rating or better, The roof of the enclosure shall be 10 gauge galvanized sheet metal supported to meet snow loading building codes for Fairbanks, Alaska. The compartments shall be arranged in the field so that the knockout tank compartment is at the south end of the enclosure, the vacuum pump, motor, separator tank, and heat exchanger in the north compartment. The oil/water separator compartment will be connected to the west side of the knockout tank compartment. The compartments shall be open where they connect to the knockout tank compartment to receive heat and air flow. See attached Engineering Drawing EIE-100-002 for more details.

B. Process Data

Design condition:

Gas flow rate (up to):	500 SCFM
Specific gravity (air = 1.0):	Approx. 2.4 at start up gasoline/vapor/air mixture approx. 50% gasoline at start-up (will approach air with operation)
Heat of combustion:	Approx. 3,1000 BTU/SCF at start-up gasoline vapor/air mixture approx. 50% gasoline at start-up (will approach air with operation)
Temperature:	60 to 140 degrees Fahrenheit
Wind velocity (radiation):	20 mph

Utilities available:

Pilot system

Operation:	Manual on-off
Fuel:	Propane (LPG)
Pressure:	5 - 30 psig
Temperature:	Ambient (Fairbanks, AK)
Specific gravity (air = 1.0):	1.53 (specific gravity of propane vapor)

Flame generator system:

Operation:	Manual on-off
Fuel:	Propane (LPG)
Pressure:	5 - 30 psig
Temperature:	Ambient (Fairbanks, AK)
Specific gravity:	1.53 (specific gravity of propane vapor)
Fluid:	Air (Subcontractor/Manufacturer needs to air at pressure required to generate negative pressure in the venturi).
Sparking:	Electrical

Snuffing system:

Operation:	Manual on-off
Fluid:	Carbon dioxide (bottle)

C. Mechanical Data

Tip diameter:	Manufacturer's standard
Tip length:	Manufacturer's standard
Seal diameter:	Seal contained in tip
Seal length:	Manufacturer's standard
Elevation:	40 feet above ground surface
Tip material:	310 stainless steel
Seal Material:	310 stainless steel
Wind deflectors:	310 stainless steel
Flame retention ring:	310 stainless steel

Lifting lugs:	310 stainless steel
Mounting brackets:	A-285C
Connections:	All flanged connections shall be 150 lb. RF Wn Flange, A-105 C.S. (all screwed connections necessary shall be rated at 6000#).
Corrosion allowance:	Stainless steel - 1/16 inch Carbon steel - 1/8 inch
Surface preparation C.S.:	Sandblast spec. 900 Painting spec. 920
Piping:	ANSI B31.3 100% radiograph
Refractory lining:	Manufacturer's standard
Painting:	All stainless steel items shall have a neutral finish. Carbon steel items shall be prepared and coated per Spec. 900 and 920.

FLARE TIP DATA SHEET

1.0 Pressure Drop

Flare Gas Rate MMSCFD	Exit Mach	Pressure Drop inches of Water Column Tip	Seal	Total
0.50	.11	5.2	1.3	6.5
0.75	.17	11.7	2.8	14.5
1.0	.23	20.3	5.0	25.3
2.0	.45	74.4	19.0	94.4

2.0 Pilot System

Gas per pilot 50 SCFH @ 10 psig

3.0 Flame generator system

Gas required 100 SCFH @ 6 psig
Air usage required 1000 SCFH @ 6 psig (sytem provided by the Subcontractor)

4.0 Absolute Radiation Levels

BTU/HR Sq. FT (no solar included) See computer data for details.
40 feet above ground level (zero level)
Determine absolute radiation levels for each flare gas rate

Elevation above zero level	Radiation level @ 20 mph wind Horizontal distance from base of flare stack				
Feet	0 ft.	20 ft.	40 ft.	60 ft.	80 ft.
0	See computer data sheets				
10					
20					
30					
35					
40					
50					

In lieu of completing the above table, the Subcontractor shall submit a computer generated stack/ height radiation diagram.

5.0 Weight

Total flare assembly including pilots, manifolds, etc. 300 lbs.
Total pipe stack assembly 600 lbs.

6.0 Drawings

General arrangement drawings of the tip, seal, burners, pilots, wind deflectors, retention ring and pipe stack.

ALLIED FLARE, INC.
P.O. BOX 58294 • HOUSTON, TEXAS 77258

THIS IS A THREE-PART PROGRAM FOR DESIGNING PIPE FLARES.

PART ONE CALCULATES EXIT VELOCITY, SONIC VELOCITY, MACH NUMBER, API FLAME LENGTH, PURGE RATE, HEAT RELEASE AND FLARE TIP PRESSURE DROP. REQUIRED INPUTS ARE FLOW IN MMSCFD, AVERAGE MOLECULAR WEIGHT, STREAM TEMPERATURE IN DEG F, FLARE TIP O.D. AND WALL THICKNESS IN INCHES AND FLARE TIP LENGTH IN FEET. ALSO REQUIRED ARE THE RATIO OF SPECIFIC HEATS, HHV AND LHV IN BTU/SCF; IF THESE VALUES ARE NOT PROVIDED, THE PROGRAM WILL CALCULATE DEFAULT VALUES. ROUGHNESS IS .0018 FOR NEW PIPE. THE PROGRAM ASKS FOR THE LOWER EXPLOSIVE LIMIT WHICH WILL BE USED IN PART TWO. PART TWO CALCULATES THE FLAME CENTER BASED ON DATA FROM PART ONE AND ADDITIONAL INPUT ON THE WIND VECTOR AND RELATIVE HUMIDITY. INPUTS ARE WIND DIRECTION RELATIVE TO THE FLARE, WIND SPEED IN FPS (.03 FPS MIN. = DEFAULT VALUE) AND REL. HUMIDITY IN %. PART THREE CALCULATES THE RADIATION AT SPECIFIED POINTS RELATIVE TO THE TIP OF THE FLARE. RADIATED HEAT/TOTAL HEAT RELEASE (F FACTOR) DEFAULT VALUE IS 0.2. THE RADIATION LEVELS ARE CALCULATED FROM A POINT SOURCE MODEL. THE MODEL USED IS THAT OF BRZUSTOWSKI, API RP 521.

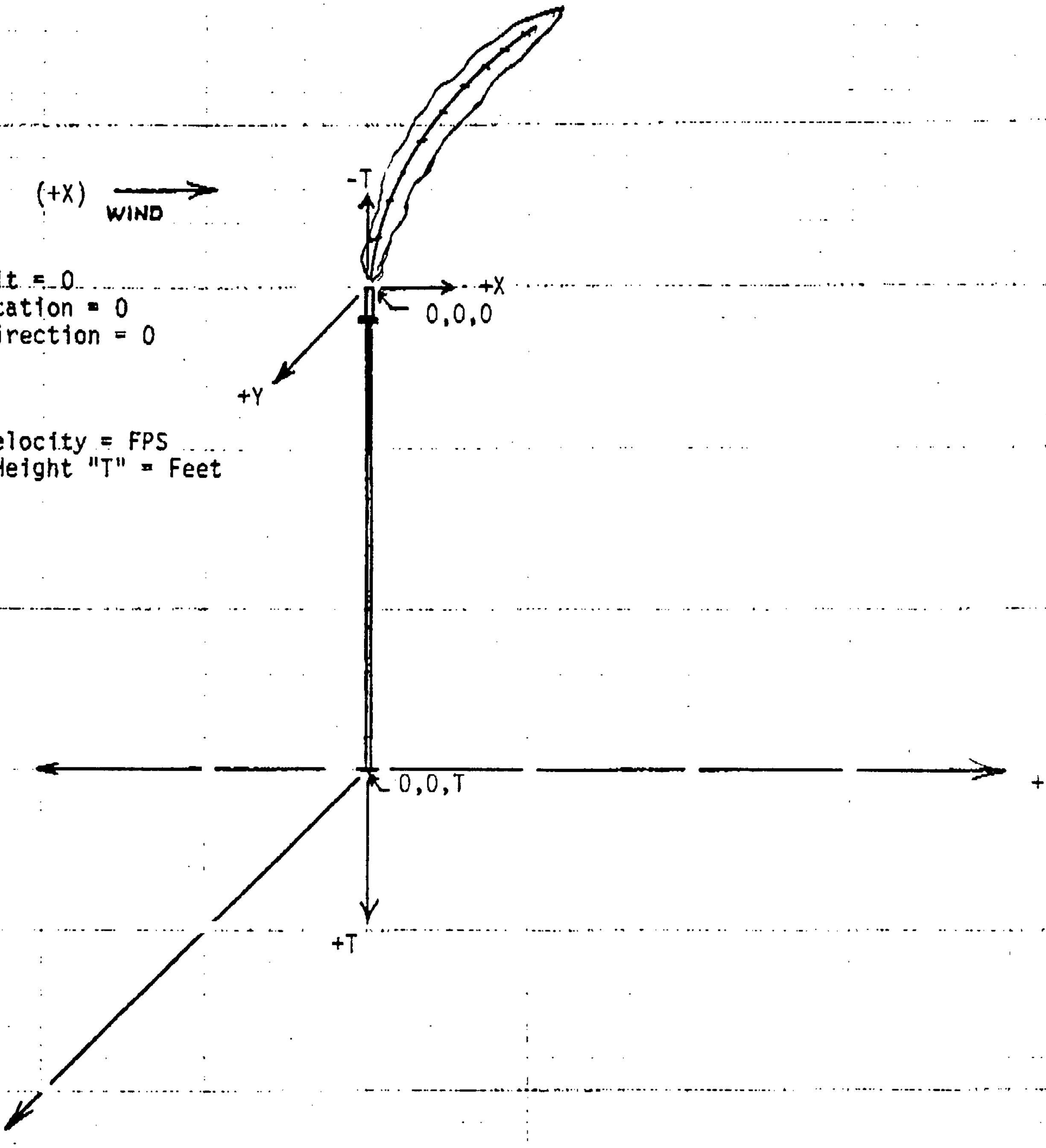
AT THE END OF EACH PART, YOU ARE GIVEN THE OPTION OF RETURNING AND RERUNNING PORTIONS OF THE PROGRAM, CHANGING WHATEVER DATA YOU WISH.

PHONE: (713) 486-7631 •

ALLIED FLARE inc.
HOUSTON, TEXAS

SUBJECT: Flare Flame Shape
Coordinate System Used
In Computer Prgrm
DATE: 12-0-89

SHEET NO.:
ENG NO.:
BY: TEH



Tip Tilt = 0
Tip Rotation = 0
Wind Direction = 0

Wind Velocity = FPS
Flare Height "T" = Feet

SS DATA DATE: 03-27-1992 TIME: 17:12:17 FILE NO: 629 -01

FLOWRATE, MMSCFD	2	MAX FLOW
MOLECULAR WEIGHT	69.6	
TEMP, DEG F	140	
GAMMA	1.055782	
LOWER EXPL. LIMIT	.05	
HHV, BTU/SCF	3100	
LHV, BTU/SCF	2800	
HEAT RELEASE, BTU/HR	2.333352E+08	
FRACT. OF HEAT RADIATED	.2	
LAPI, FT	63	

UTILITY DATA

PURGE RATE, SCFH	10

MECHANICAL DATA

TIP DIAMETER (OD), IN.	4.5	
TIP LENGTH, FT.	12	
EXIT VELOCITY, FPS	306	
MACH NO.	.45	
TIP PRESS.DROP, IN OF H20	93.4	= 3.4 PSIG
DIODE SEAL	YES	
FLAME STABILIZER	YES	
EXIT VEL.HEAD INCL.	YES	
90 DEG LR EL	NO	

SHAPE PERAMETERS DATE: 03-27-1992 TIME: 17:12:27 FILE NO: 629

FLAME LENGTH IN FEET	62.9	
WIND VELOCITY IN FPS	29	= 20 MPH
WIND DIRECTION IN DEGREES	0	
RELATIVE HUMIDITY, %	60	

FLAME CENTER

X(C), ft.	1.538732
Z(C), ft.	7.414794

RADIATION LEVELS (BTU/Hr.-Sq.Ft.)

X, ft. / Y, ft.	50	100	150	200	250
50	546	231	116	68	44
100	216	139	87	57	39
150	108	85	62	45	33
200	64	55	44	34	27

GAS DATA DATE: 03-27-1992 TIME: 17:12:59 FILE NO: 629-02

FLOWRATE, MMSCFD	1	NORM FLOW
MOLECULAR WEIGHT	69.6	
TEMP, DEG F	140	
GAMMA	1.055782	
LOWER EXPL. LIMIT	.05	
HHV, BTU/SCF	3100	
LHV, BTU/SCF	2800	
HEAT RELEASE, BTU/HR	1.166676E+08	
FRACT. OF HEAT RADIATED	.2	
LAPI, FT	45	

UTILITY DATA

PURGE RATE, SCFH 10

MECHANICAL DATA

TIP DIAMETER (OD), IN.	4.5
TIP LENGTH, FT.	12
EXIT VELOCITY, FPS	153
MACH NO.	.23
TIP PRESS.DROP,IN OF H20	25.3 = .92
DIODE SEAL	YES
FLAME STABILIZER	YES
EXIT VEL.HEAD INCL.	YES
90 DEG LR EL	NO

SHAPE PERAMETERS DATE: 03-27-1992 TIME: 17:13:08 FILE NO: 629

FLAME LENGTH IN FEET	45.1
WIND VELOCITY IN FPS	29 = 20 MPH
WIND DIRECTION IN DEGREES	0
RELATIVE HUMIDITY, %	60

FLAME CENTER

X(C), ft. 2.143133
Z(C), ft. 4.939075

RADIATION LEVELS (BTU/Hr.-Sq.Ft.)

X.ft. / T,ft.	50	100	150	200	250
50	291	119	59	34	22
100	113	72	44	29	20
150	56	43	31	23	17
200	33	28	22	17	14

GAS DATA DATE: 03-27-1992 TIME: 17:13:39 FILE NO: 629 - 03

FLOWRATE, MMSCFD	.75 — 10 flow
MOLECULAR WEIGHT	69.6
TEMP, DEG F	140
GAMMA	1.055782
LOWER EXPL. LIMIT	.05
HHV, BTU/SCF	3100
LHV, BTU/SCF	2800
HEAT RELEASE, BTU/HR	8.750071E+07
FRACT. OF HEAT RADIATED	.2
LAPI, FT	39

UTILITY DATA

PURGE RATE, SCFH	10

MECHANICAL DATA

TIP DIAMETER (OD), IN.	4.5
TIP LENGTH, FT.	12
EXIT VELOCITY, FPS	115
MACH NO.	.17
TIP PRESS.DROP, IN OF H20	14.5
DIODE SEAL	YES
FLAME STABILIZER	YES
EXIT VEL.HEAD INCL.	YES
90 DEG LR EL	NO

SHAPE PERAMETERS DATE: 03-27-1992 TIME: 17:13:49 FILE NO: 629

FLAME LENGTH IN FEET	39.3
WIND VELOCITY IN FPS	29 — 20 mph
WIND DIRECTION IN DEGREES	0
RELATIVE HUMIDITY, %	60

FLAME CENTER

X(C), ft.	2.608902
Z(C), ft.	4.242327

RADIATION LEVELS (BTU/Hr.-Sq.Ft.)

X, ft. / T, ft.	50	100	150	200	250
50	223	91	45	26	17
100	86	55	34	22	15
150	42	33	24	17	12
200	25	21	17	13	10

ESS DATA   DATE: 03-27-1992   TIME: 17:09:14   FILE NO: 629 - 04

FLOWRATE, MMSCFD	.5 ← min flow
MOLECULAR WEIGHT	69.6
TEMP. DEG F	140
GAMMA	1.055782
LOWER EXPL. LIMIT	.05
HHV, BTU/SCF	3100
LHV, BTU/SCF	2800
HEAT RELEASE, BTU/HR	5.83338E+07
FRACT. OF HEAT RADIATED	.2
LAPI, FT	32

UTILITY DATA

PURGE RATE, SCFH	10

MECHANICAL DATA

TIP DIAMETER (OD). IN.	4.5
TIP LENGTH, FT.	12
EXIT VELOCITY, FPS	77
MACH NO.	.11
TIP PRESS.DROP, IN OF H20	6.5
DIODE SEAL	YES
FLAME STABILIZER	YES
EXIT VEL.HEAD INCL.	YES
90 DEG LR EL	NO

E SHAPE PERAMETERS   DATE: 03-27-1992   TIME: 17:09:24   FILE NO: 629

FLAME LENGTH IN FEET	32.4
WIND VELOCITY IN FPS	15 — calm winds
WIND DIRECTION IN DEGREES	0
RELATIVE HUMIDITY, %	60

FLAME CENTER

X(C), ft.	2.159384
Z(C), ft.	4.830182

RADIATION LEVELS (BTU/Hr.-Sq.Ft.)

X, ft. / T, ft.	50	100	150	200	250
50	146	60	30	17	11
100	57	36	22	14	10
150	28	22	16	11	8
200	16	14	11	9	7

SHAPE PERAMETERS DATE: 03-27-1992 TIME: 17:10:53 FILE NO: 629 -05

FLAME LENGTH IN FEET	32.4	MIN FLOW
WIND VELOCITY IN FPS	29 -20 MPH	
WIND DIRECTION IN DEGREES	Ø	
RELATIVE HUMIDITY, %	60	

FLAME CENTER

X(C), ft.	3.183272
Z(C), ft.	3.349769

RADIATION LEVELS (BTU/Hr.-Sq.Ft.)

X, ft.	50	100	150	200	250
T, ft.					
50	154	62	30	17	11
100	58	37	23	15	10
150	29	22	16	11	8
200	17	14	11	9	7

ALLIED FLARE INC.
HOUSTON, TEXAS

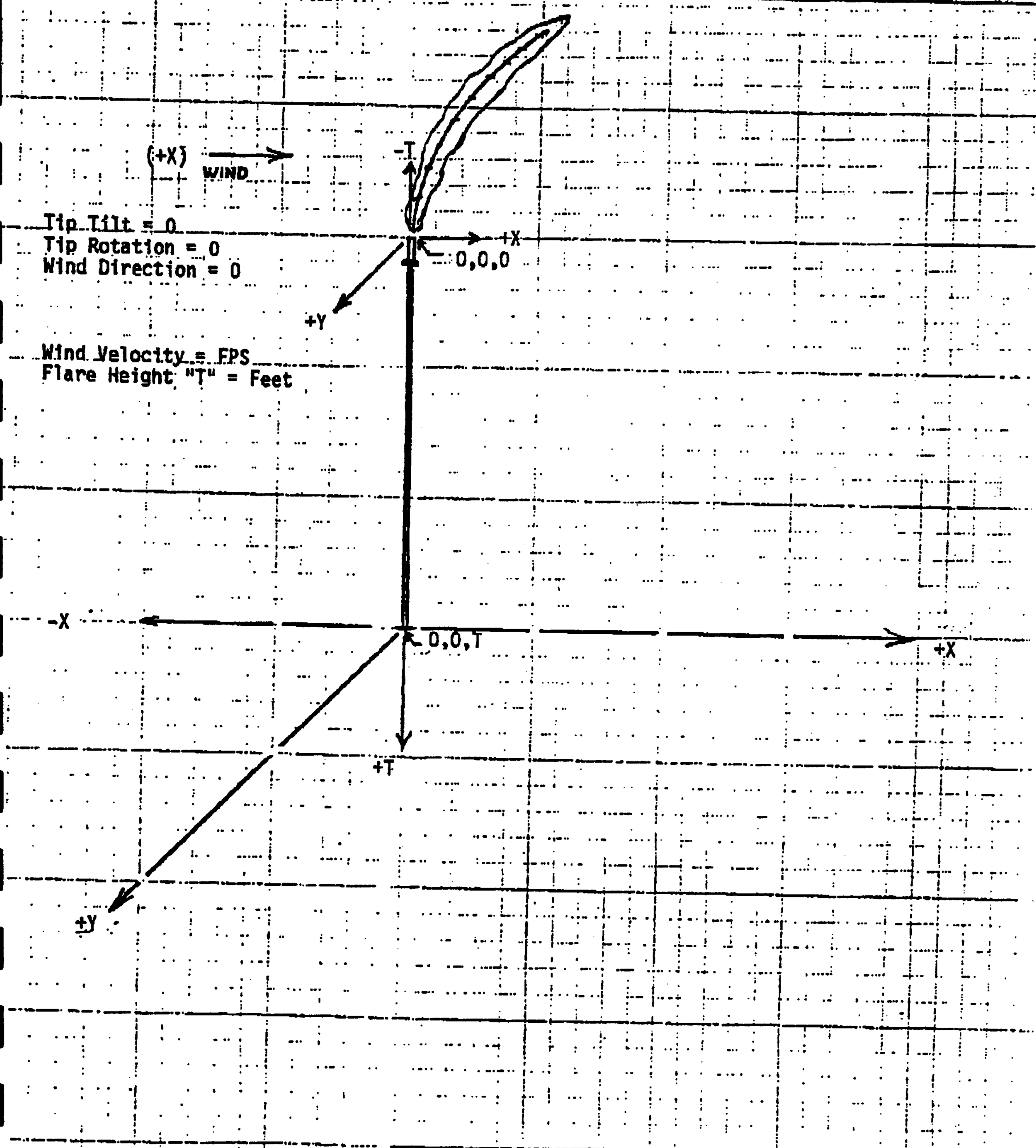
SUBJECT Flare Flame Shape
Coordinate System Used
In Computer Prgrm

DATE 12-0-89

SHEET NO.

ENG NO.

BY TEH



PROCESS DATA DATE: 06-04-1992 TIME: 12:17:42 FILE NO: 629

FLOWRATE. MMSCFD	.72
MOLECULAR WEIGHT	69.6
TEMP, DEG F	140
GAMMA	1.055782
LOWER EXPL. LIMIT	.05
HHV, BTU/SCF	3100
LHV, BTU/SCF	2800
HEAT RELEASE, BTU/HR	8.400068E+07
FRACT. OF HEAT RADIATED	.2
LAPI, FT	39

UTILITY DATA

PURGE RATE, SCFH	23

MECHANICAL DATA

TIP DIAMETER (OD), IN.	6.5
TIP LENGTH, FT.	10
EXIT VELOCITY, FPS	49
MACH NO.	.07
TIP PRESS.DROP, IN OF H20	2.3
DIODE SEAL	YES
FLAME STABILIZER	YES
EXIT VEL.HEAD INCL.	YES
90 DEG LR EL	NO

AME SHAPE PERAMETERS DATE: 06-04-1992 TIME: 12:18:11 FILE NO: 629

FLAME LENGTH IN FEET	38.6
WIND VELOCITY IN FPS	29
WIND DIRECTION IN DEGREES	0
RELATIVE HUMIDITY, %	60

FLAME CENTER

X(C), ft.	5.425514
Z(C), ft.	3.776495

RADIATION LEVELS (BTU/Hr.-Sq.Ft.)

X, ft. T, ft.	50	100	150	200	250
50	229	92	45	26	16
100	85	54	33	21	15
150	41	32	23	17	12
200	24	21	16	13	10

Jacobs Engineering Group
Lakeland, FL

Inter-Office Memo

To Mo Madden - Denver

From Dave Kirkby - Lklnd.

Date April 22, 1992

Subject Eielson D.O. 4 Treatability Study - Pressure Drops

Finally got the pressure drop info done for you. Enclosed are following:

1) Velocities & Pressure drops of oil & water in 1", 1½" & 2" lines. As I mentioned to you before, the vacuum generated by the pump will only lift a column of oil or water just so far. For example; at 15 in Hg vacuum which is equivalent to 7.37 psi, you will lift a column of water ~17 ft or a column of oil ~ 21.3 ft. Therefore, with 15 in of vacuum, you can't get water out of the bottom of a 20 ft. deep hole!

2) Velocities & Pressure drops in VEW header and lateral lines from wells to vacuum pump inlet. For pressure drops in inches of Hg., multiply psi/100' by 2.036.

3) Velocities & Pressure drops in 1", 1½" and 2" drawdown tubes at 5, 10, 15 in Hg vacuum. This is for vapor flow only (air saturated with gasoline and water at 40°F and the pressure in question). You will note I have indicated that a certain velocity shouldn't be exceeded. This is the generally accepted max. velocity for a compressor or vacuum pump suction or inlet line.

Jacobs Engineering Group
Lakeland, FL

Inter-Office Memo

To Mo Madden

From Dave Kirkby

Date April 22, 1992

Subject

3) cont'd. You will note pressure drops are not a problem, but the max. velocities are exceeded at relatively low flows.

4) On the subject of two phase flow; I have not worked on this although I have considered how many cases would have to be calculated. A great deal of work is involved because:

a. Three pressure cases have to be investigated; 5, 10 & 15 in Hg vac.

b. Three different drawdown tubes sizes need evaluating 1", 1½ and 2"

c. The wt. ratio of vapor to liquid should be taken over a wide range. For example from a V/L (wt.) of say 0.5 to a V/L of 8-10. (Volume ratios are meaningless because a cubic foot of gas doesn't correlate to a cubic foot of liquid)

d. There are two cases for each of the above; i.e. 1) vapor (air sat. d/w/ gaso + water) together with gasoline liquid and 2) vapor together with water liquid

Jacobs Engineering Group
Lakeland, FL

Inter-Office Memo

To Mo Madden

From DAVE KIRKBY

Date 4/22/92

Subject

4) Cont'd -

With all of the above possible combinations of case, I figure there will be about 200 separate two phase flow calculations, which will require about 80-90 hours, including correlation and evaluation time. I doubt if the project can afford this.

If you have any questions, please call

Cheers

Dave

JACOBS ENGINEERING GROUP INC.

ENGINEERING COMPUTATION SHEET

SUBJECT: ______ SHEET: 1 OF 2
CLIENT: ______ DATE: 2-20-92
COMPUTED BY: DK CHKD. BY: ______ JOB: ______ CONTRACT NO.: 05-G104-00

Check pressure drop in VEW Lines

assume max of 500 scfm @ 15" Hg vac.

Calc. M.W. & density @ STP for mass flow

10# gaso. V.P. = 5.4 psia @ 60°F
water V.P. = 0.256

M.W.

		m.f.	M.W	wt.
gaso	5.4 / 14.7 =	0.367	110	40.37
H_2O	0.256 / 14.7 =	0.017	18	0.3
air	(by diff) =	(0.616)	28.9	17.80
		1.0		58.47

M.W = 58.5

$$\rho_v @ STP = \frac{58.5(14.7)}{10.73(520)} = 0.154 \ lb/ft^3$$

@ max. flow of 500 scfm mass flow = 0.154 × 500 × 60
= 4620 lb/hr

Flow from 1 well = 4620/9 = 513 lb/hr
2 wells = 1026 lb/hr
3 wells = 1539
4 wells = 2052
5 wells = 2565

$$V_{max} = 20/\sqrt{\rho_v}$$
$$= 20/\sqrt{0.154}$$
$$\cong 51 \ fps$$

JACOBS ENGINEERING GROUP INC.

ENGINEERING COMPUTATION SHEET

SUBJECT:
CLIENT:
COMPUTED BY: JL CHKD. BY: JOB:

DATE: 2/20/92
CONTRACT NO.: 05-9104-00

Check pressure drop in VEW line

@ 15" Hg vac, 14.9 in Hg abs,
7.3 psia

@ 40°F V.P. Gaso = 3.7 psia
V.P. H_2O = 0.12 psia

M.W. of gas

		M.f.	MW	wt.
gaso	3.7/7.3 =	0.507	110	55.77
H_2O	0.12/7.3 =	0.016	18	~0.3
air	(by diff) =	(0.477)	28.9	13.79
		1.0		69.86

MW = 69.9

$$\rho_v @ 40° \text{ \& } 7.3 \text{ psia} = \frac{69.9(7.3)}{10.73(500)} = \underline{0.095 \text{ lb/ft}^3}$$

$$V_{max} = 20/\sqrt{\rho_v}$$
$$= 20/\sqrt{0.095}$$
$$= 65 \text{ fps}$$

MMMMMMMMMMMMMMMMMMMMM VARIABLE SHEET MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM

St	Input	Name	Output	Unit	Comment
	513	F		LB/HR	FLOW RATE
		Q	673.272	gpm	FLOW RATE
	.095	RHO		lb/ft^3	DENSITY
		SG	.0015239		SPECIFIC GRAVITY
	.015	VIS		cP	VISCOSITY
	3.068	d		INCHES	PIPE DIAMETER
		V	29.218215	ft/sec	VELOCITY
		Re	70451.108		REYNOLDS NUMBER
		f	.02166132		FRICTION FACTOR
		DP	.07421053	psi/100'	PRESSURE DROP

<u>Flow from 1 well</u>

acfm = 90

```
MMMMMMMMMMMMMMMMMMMMM VARIABLE SHEET MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM
St InputDDDD NameDDD OutputDDD UnitDDDDD CommentDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
   1026      F                 LB/HR     FLOW RATE
             Q       1346.544  gpm       FLOW RATE
   .095      RHO               lb/ft^3   DENSITY
             SG      .0015239            SPECIFIC GRAVITY
   .015      VIS               cP        VISCOSITY
   3.068     d                 INCHES    PIPE DIAMETER
             V       58.43643  ft/sec    VELOCITY
             Re      140902.22           REYNOLDS NUMBER
             f       .01988952           FRICTION FACTOR
             DP      .2725618  psi/100'  PRESSURE DROP
```

Vel is high

flow from 2 wells

acfm = 180

```
MMMMMMMMMMMMMMMMMMMMMM VARIABLE SHEET MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM
St InputDDDD NameDDD OutputDDD UnitDDDDD CommentDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
   1026      F                 LB/HR     FLOW RATE
             Q       1346.544  gpm       FLOW RATE
   .095      RHO               lb/ft^3   DENSITY
             SG      .0015239            SPECIFIC GRAVITY
   .015      VIS               cP        VISCOSITY
   4.026     d                 INCHES    PIPE DIAMETER
             V       33.934921 ft/sec    VELOCITY
             Re      107374.07           REYNOLDS NUMBER
             f       .01991675           FRICTION FACTOR
             DP      .07014022 psi/100'  PRESSURE DROP
```

flow from 2 wells

use

ЖЖЖЖЖЖЖЖЖЖЖЖЖЖЖЖЖЖЖЖЖ VARIABLE SHEET ЖЖ

St	InputDDDD	NameDDD	OutputDDD	UnitDDDDD	CommentDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
	1539	F		LB/HR	FLOW RATE
		Q	2019.816	gpm	FLOW RATE
	.095	RHO		lb/ft^3	DENSITY
		SG	.0015239		SPECIFIC GRAVITY
	.015	VIS		cP	VISCOSITY
	4.026	d		INCHES	PIPE DIAMETER
		V	50.902382	ft/sec	VELOCITY → vel. ok
		Re	161061.1		REYNOLDS NUMBER
		f	.01896442		FRICTION FACTOR
		DP	.15026939	psi/100'	PRESSURE DROP

ok (0.31 in Hg)

flow from 3 wells

acfm = 270

MMMMMMMMMMMMMMMMMMMMM VARIABLE SHEET MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM

St	InputDDDD	NameDDD	OutputDDD	UnitDDDDD	CommentDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
	2052	F		LB/HR	FLOW RATE
		Q	2693.088	gpm	FLOW RATE
	.095	RHO		lb/ft^3	DENSITY
		SG	.0015239		SPECIFIC GRAVITY
	.015	VIS		cP	VISCOSITY
	4.026	d		INCHES	PIPE DIAMETER
		V	67.869842	ft/sec	VELOCITY
		Re	214748.14		REYNOLDS NUMBER
		f	.01841927		FRICTION FACTOR
		DP	.25946625	psi/100'	PRESSURE DROP

vel. is high check 6"

flow from 4 wells

```
ИИИИИИИИИИИИИИИИИИИИИИ VARIABLE SHEET ИИИИИИИИИИИИИИИИИИИИИИИИИИИИИИИИИИИИИИИИИИИИИИИИИ
St InputDDDD NameDDD OutputDDD UnitDDDDD CommentDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
   2052      F                 LB/HR     FLOW RATE
             Q       2693.088  gpm       FLOW RATE
   .095      RHO               lb/ft^3   DENSITY
             SG      .0015239            SPECIFIC GRAVITY
   .015      VIS               cP        VISCOSITY
   6.065     d                 INCHES    PIPE DIAMETER
             V       29.906306 ft/sec    VELOCITY
             Re      142551.69           REYNOLDS NUMBER
             f       .01847747           FRICTION FACTOR
             DP      .03354795 psi/100'  PRESSURE DROP
```

ok

flow from 4 wells

use 6"

MMMMMMMMMMMMMMMMMMMMMMM VARIABLE SHEET MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM

St	Input	Name	Output	Unit	Comment
	2565	F		LB/HR	FLOW RATE
		Q	3366.36	gpm	FLOW RATE
	.095	RHO		lb/ft^3	DENSITY
		SG	.0015239		SPECIFIC GRAVITY
	.015	VIS		cP	VISCOSITY
	6.065	d		INCHES	PIPE DIAMETER
		V	37.382882	ft/sec	VELOCITY ok
		Re	178189.61		REYNOLDS NUMBER
		f	.0179496		FRICTION FACTOR
		DP	.05092116 ok	psi/100'	PRESSURE DROP

flow from 5 wells

MMMMMMMMMMMMMMMMMMMMM VARIABLE SHEET MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM

St	Input	Name	Output	Unit	Comment
	4620	F		LB/HR	FLOW RATE
		Q	6063.3853	gpm	FLOW RATE
	.095	RHO		lb/ft^3	DENSITY
		SG	.0015239		SPECIFIC GRAVITY
	.015	VIS		cP	VISCOSITY
	7.981	d		INCHES	PIPE DIAMETER
		V	38.884308	ft/sec	VELOCITY ← ok
		Re	243899.26		REYNOLDS NUMBER
		f	.0168394		FRICTION FACTOR
		DP	.03927776	psi/100'	PRESSURE DROP

flow from 9 wells

MMMMMMMMMMMMMMMMMMMMM VARIABLE SHEET MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM

St	Input	Name	Output	Unit	Comment
	4620	F		LB/HR	FLOW RATE
		Q	6063.3853	gpm	FLOW RATE
	.095	RHO		lb/ft^3	DENSITY
		SG	.0015239		SPECIFIC GRAVITY
	.015	VIS		cP	VISCOSITY
	6.065	d		INCHES	PIPE DIAMETER
		V	67.332911	ft/sec	VELOCITY ← Vel. is high but pipe runs are short
		Re	320949.71		REYNOLDS NUMBER
		f	.01684504		FRICTION FACTOR
		DP	.15503319	psi/100'	PRESSURE DROP

ok

Flow from 9 wells

no need to go to 8"

JACOBS ENGINEERING GROUP INC.

ENGINEERING COMPUTATION SHEET

SUBJECT: PRESSURE DROPS IN DRAWDOWN/"SLURP" TUBES SHEET: 1 OF 4
CLIENT: EIELSON AFB DATE: 4-14-92
COMPUTED BY: DK CHKD. BY: JOB: CONTRACT NO.: 05-G104-0(

CHECK SINGLE PHASE PRESS. DROPS IN 1", 1½", 2" DRAWDOWN TUBES w/ 5, 10 and 15 in Hg Vac.

SINGLE PHASE PRESSURE DROP

CHECK WATER

temp = 40°F μ = 1.5 cP
S.G ≅ 1.0 , ρ_L = 62.34 lb/ft³

the various pressures given are the maximum available pressure drops.

1" pipe

1st Trial	2nd Trial	3rd Trial
Flow = 12 gpm	Flow = say 30 gpm	Flow = say 40 gpm
V = 4.45 fps	V = 11.1 fps	V = 14.8 fps
Re = 24099	Re = 60248	Re = 80,330
f = 0.028	f = 0.025	f = 0.0247
ΔP = 4.3 psi/100 ft	ΔP = 24.2 psi/100'	ΔP = 42.0 psi/100'
for 20 ft tube	for 20 ft tube	for 20 ft tube
ΔP = 0.86 psi, ~2 ft H₂O	ΔP = 4.84 psi, 11.1 ft	ΔP = 8.4 psi, 19.4 ft
1.8 in Hg	9.9 in Hg	17.1 in Hg

JE

JACOBS ENGINEERING GROUP INC.

ENGINEERING COMPUTATION SHEET

SUBJECT: ______ SHEET: 2 OF 4

CLIENT: ______ DATE: 4-14-92

COMPUTED BY: DK CHKD. BY: ______ JOB: ______ CONTRACT NO.: 05-6104-00

WATER w/ $1\frac{1}{2}$" pipe

1st Trial	2nd Trial	3rd Trial
flow = 100 gpm	flow = 75 gpm	flow = 125 gpm
V = 15.8 fps	V = 11.8 fps	V = 19.7 fps
Re = 130,849	Re = 98136	Re = 163,561
f = 0.022	f = 0.0226	f = 0.0217
ΔP = 27.5 psi/100'	ΔP = 15.8 psi/100'	ΔP = 42.3 psi/100'
for 20 ft tube,	for 20 ft tube,	for 20 ft tube,
ΔP = 5.5 psi, 12.7 ft	ΔP = 3.2 psi, 7.3 ft	ΔP = 8.47 psi, 19.6 ft
11.2 in Hg	6.5 in Hg	17.2 in Hg.

WATER w/ 2" pipe

1st TRIAL	2nd Trial	3rd Trial
flow = 100 gpm	flow = 200 gpm	flow = 250 gpm
V = 9.6 fps	V = 19.1 fps	V = 23.9 fps
Re = 101,919	Re = 203838	Re = 254,798
f = 0.0217	f = 0.0205	f = 0.0202
ΔP = 7.7 psi/100'	ΔP = 29.28 psi/100'	ΔP = 45.15 psi/100'
for 20 ft pipe,	for 20 ft pipe,	for 20 ft pipe,
ΔP = = 1.6 psi, 3.5 ft	ΔP = 5.9 psi, 13.5 ft	ΔP = 9.0 psi, 20.9 ft,
3.2 in Hg	12.0 in Hg	18.4 in Hg

JACOBS ENGINEERING GROUP INC.

ENGINEERING COMPUTATION SHEET

SUBJECT:

CLIENT:

COMPUTED BY: DK CHKD. BY: JOB:

SHEET: 3 OF 4

DATE: 4-14-92

CONTRACT NO.: 05-G106-00

OIL PRESSURE DROP

ASSUME OIL IS GASOLINE @ 60°F μ = 0.75 cP
S.G. ≅ 0.8

GASOLINE W/ 1" PIPE

1st	2nd	3rd
Flow = 50 gpm	25 gpm	15 gpm
V = 18.5 fps	V = 9.3 fps	V = 5.6
Re = 160,660	Re = 80,330	Re = 48,199
f = 0.0237	f = 0.0247	f = 0.026
ΔP = 50.3 psi/100'	ΔP = 13.1 psi/100'	ΔP = 4.96 psi/100'
for 20' tube,	for 20 ft tube,	for 20 ft tube
ΔP = 10.1 psi,	ΔP = 2.6 psi	ΔP ≅ 1.0 psi
29.2 ft,	7.5 ft	2.9 ft
20.6 in Hg	5.3 in Hg	2.0 in Hg

GASOLINE W/ 1½" PIPE

Flow = 75 gpm	100 gpm	150 gpm
V = 11.8 fps	V = 15.8	V = 23.6
ΔP = 12.2 psi/100'	ΔP = 21.4 psi/100'	ΔP = 47.2 psi/100'
for 20 ft tube,	for 20 ft tube,	for 20 ft tube
2.44 psi,	ΔP = 4.3 psi,	ΔP = 9.44 psi,
7.0 ft,	12.4 ft,	27.3 ft
~5 in Hg	8.7 in Hg	19.2 in Hg.

JE

JACOBS ENGINEERING GROUP INC.

ENGINEERING COMPUTATION SHEET

SUBJECT:
CLIENT:
COMPUTED BY: DK   CHKD. BY: JOB:

DATE: 4-14-92
CONTRACT NO.: 05-G104-00

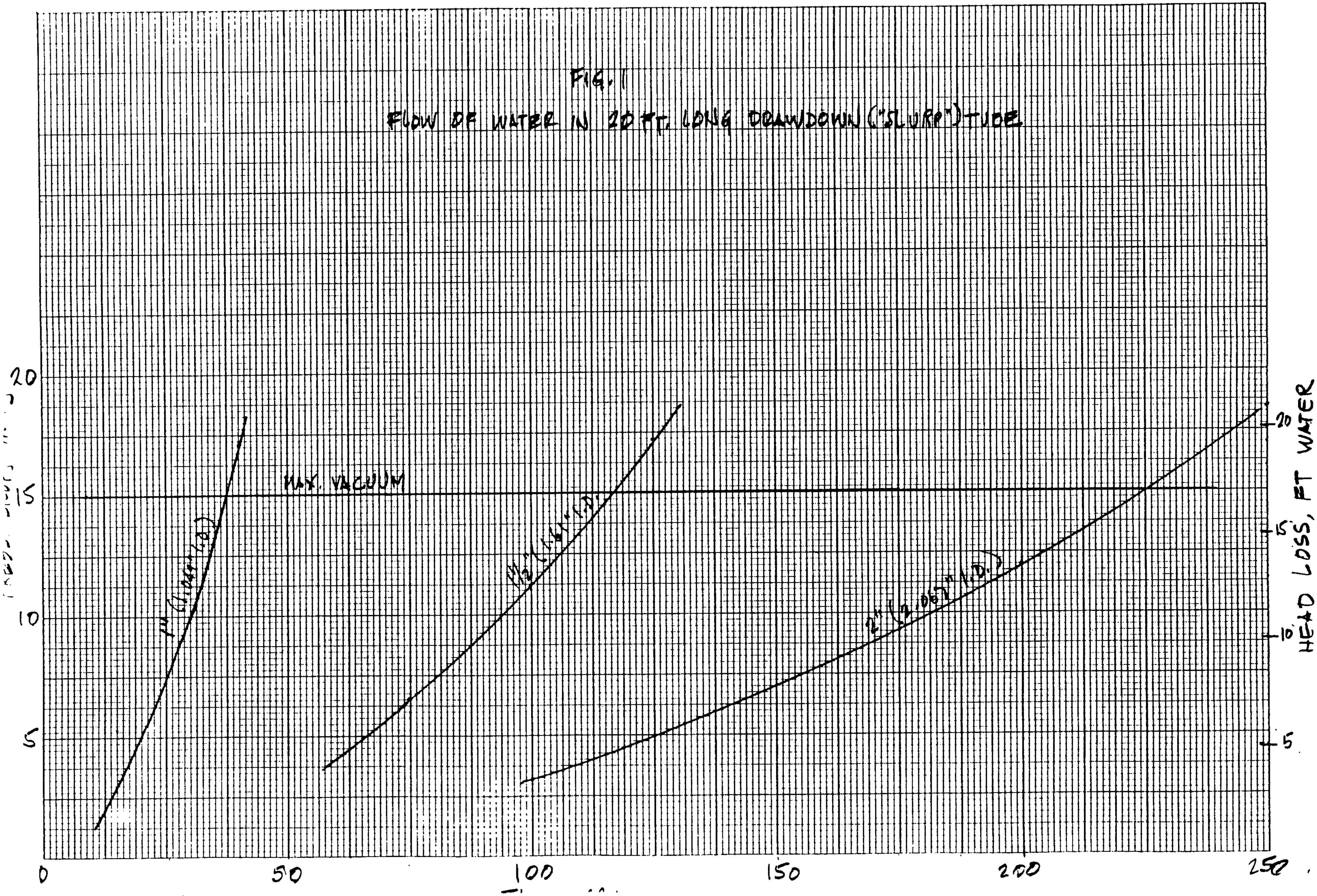
GASOLINE W/ 2" PIPE

Flow = 125 gpm	225 gpm	175 gpm
V = 11.95 fps	V = 21.5	V = 16.7
ΔP = 9.2 psi/100'	ΔP = 28.8 psi/100'	ΔP = 17.6 psi/100'
for 20 ft pipe,	for 20 ft pipe,	for 20 ft pipe.
ΔP = 1.6 psi,	ΔP = 5.8 psi	ΔP = 3.5 psi,
5.3 ft,	16.6 ft,	10.2 ft,
3.7 in Hg	11.7 in Hg	7.1 in Hg

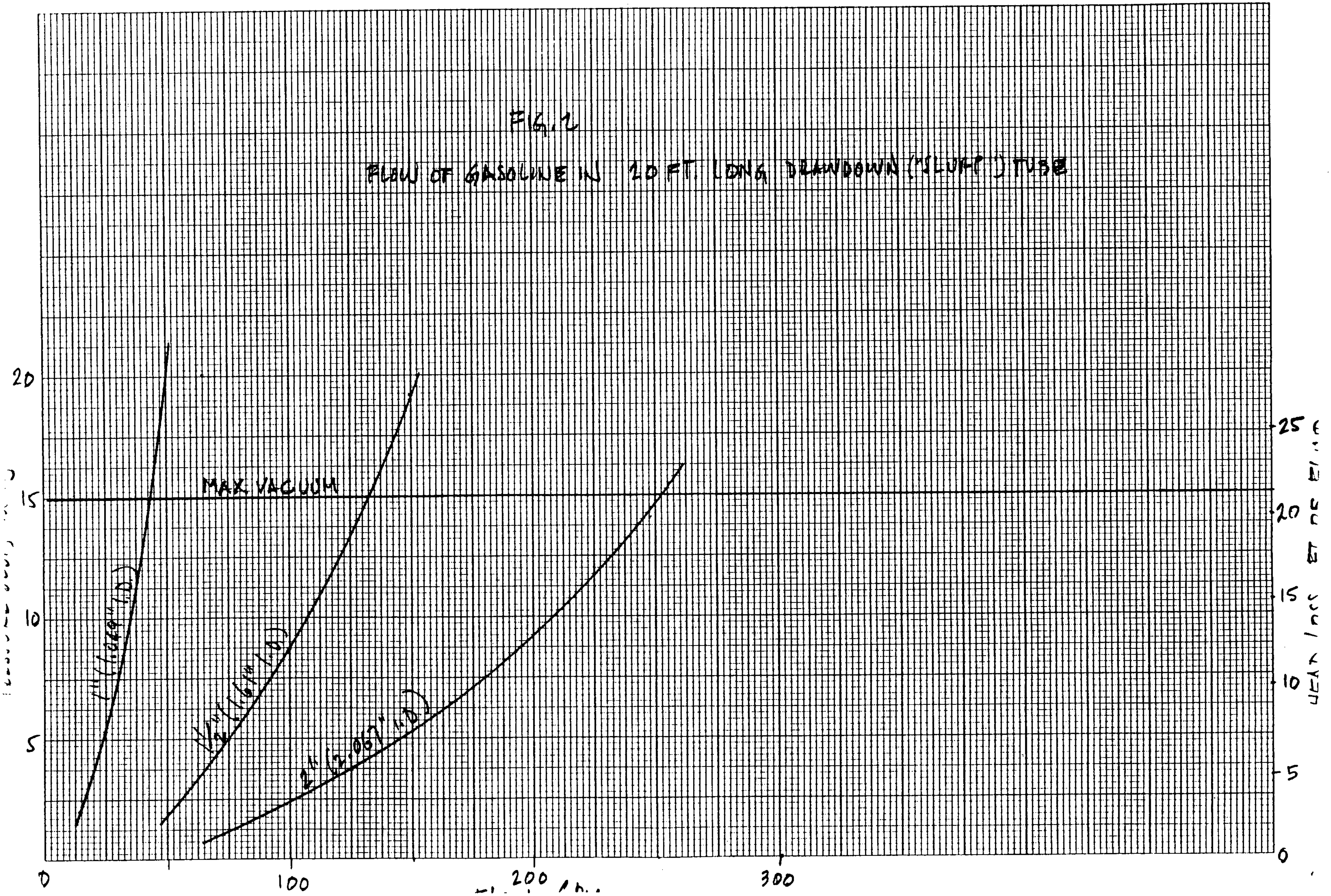
K+E 10 X 10 TO ½ INCH 7 X 10 INCHES
KEUFFEL & ESSER CO MADE IN U.S.A.
46 1323

FIG. 1

FLOW OF WATER IN 20 FT. LONG DRAWDOWN ("SLURP") TUBE



K•E 10 X 10 TO ½ INCH 7 X 10 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A. 46 1323



JACOBS ENGINEERING GROUP INC.

ENGINEERING COMPUTATION SHEET

SUBJECT:
CLIENT:
COMPUTED BY: DL CHKD. BY: JOB:

DATE: 4-21-92
CONTRACT NO. 05-9104-00

VAPOR AND 2-PHASE PRESSURE DROPS

CHARACTERIZE VAPOR, LIQUID PHASES @ 40°F & VARIOUS PRESSURES

1. @ 40°F & 5 in Hg vac.

Vapor

VP of gaso/Kero $\cong$ 3.7 psia (10# RVP gaso)
VP of H_2O = 0.12 psia

5 in Hg vac $\cong$ 24.9 "Hg Abs. = 12.2 psia

M.W.			M.f.	M.W.	lbs
gaso.	3.7 / 12.2	=	0.303	110	33.33
H_2O	0.12 / 12.2	$\cong$	0.01	18	0.18
air (by diff)		=	(0.687)	28.9	19.85
			1.0		53.36

MW = 53.4

$$\rho_v @ 40°F \ \& \ 12.2 \text{ psia} = \frac{53.4(12.2)}{10.73(500)} = \underline{0.121 \text{ lb/ft}^3}$$

$\mu \cong 0.015$ cP

$V_{max} = 20/\sqrt{0.121} = 57.5$ fps

WATER

S.G ~ 1.0, 62.34 lb/ft³
μ = 1.5 cP
σ = 75 dyne/cm

H.C.

S.G. = 0.8 49.8 lb/ft³
μ = 0.75
σ = 24 dyne/cm.

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JACOBS ENGINEERING GROUP INC.

ENGINEERING COMPUTATION SHEET

SUBJECT: ______ SHEET: 2 OF 5

CLIENT: ______ DATE: 4/21/92

COMPUTED BY: DK CHKD. BY: ______ JOB: ______ CONTRACT NO.: 05-9104-00

VAPOR @ 40°F & 10 in Hg Vac

10" Hg Vac ≅ 19.9 in Hg abs
= 9.8 psia

M.W. of gas

		M.f.	M.W	wt.
gaso	3.7/9.8 =	0.378	110	41.58
H_2O	0.12/9.8 =	0.012	18	0.22
air (by diff)	=	0.610	28.9	17.63
		1.0		59.43

MW = 59.43

$$\rho_{v @ 40°F \,\&\, 9.8 psia} = \frac{59.43(9.8)}{10.73(500)} = \underline{0.109\ lb/ft^3}$$

$\mu \cong 0.015$ cP

$V_{max} = 20/\sqrt{0.109} = 60.6$ fps

VAPOR @ 40°F & 15 in Hg Vac

15" Hg Vac ≅ 14.9 in Hg abs
= 7.3 psia

M.W. of gas

		M.f.	M.W	wT
gaso	3.7/7.3	0.507	110	55.77
H_2O	0.12/7.3	0.016	18	~ 0.3
air (by diff.)		(0.477)	28.9	13.79
		1.000		69.86

MW = 69.9

$$\rho_{v @ 40°F \,\&\, 7.3 psia} = \frac{69.9(7.3)}{10.73(500)} = \underline{0.095\ lb/ft^3}$$

$$V_{max} = 20/\sqrt{\rho_v}$$
$$= 20/\sqrt{0.095}$$
$$= 64.9$$

JE JACOBS ENGINEERING GROUP INC.

ENGINEERING COMPUTATION SHEET

SUBJECT: ______ SHEET: 3 OF 5

CLIENT: ______ DATE: 4-21-92

COMPUTED BY: DK CHKD. BY: ______ JOB: ______ CONTRACT NO.: ______

VAPOR FLOWS IN 1", 1½", 2" "SLURP" Tubes @ 5" Hg Vac @ WELL HEAD.

Vapor @ 40°F & 5 in Hg Vac

$\rho_V = 0.121\ lb/ft^3$

$\mu \cong 0.015\ cP$

vel should not exceed $20/\sqrt{\rho_V}$

or $\frac{20}{\sqrt{0.121}} = 57.5\ ft/sec.$

Since line is essentially suction to vac. pump, Velocity should also not exceed ~ 7% of Sonic vel.

$$V_{sonic} = 68 \sqrt{\frac{P(k)}{\rho_V}}$$

$k = c_p/c_V \cong 1.4$

$P = 12.2\ psia$

$\rho_V = 0.121\ lb/ft^3$

$$= 68 \sqrt{\frac{12.2(1.4)}{0.121}}$$

$$= 808\ fps$$

7% of V_{sonic} = 56.6 fps

JACOBS ENGINEERING GROUP INC.

ENGINEERING COMPUTATION SHEET

SUBJECT: ______ SHEET: 4 OF 5
CLIENT: ______ DATE: 6/21/92
COMPUTED BY: DK CHKD. BY: ______ JOB: ______ CONTRACT NO.: 05-G104-00

Vapor flows in drawdown tubes at variable pressures —

Basis! — 1. air saturated w/ gasoline vapor and water at pressure and 40°F.

2. Velocity should not exceed V_{max} based on $20/\sqrt{\rho_v}$ which is approx 7% of sonic vel.,

3. 20 ft long drawdown tube

P = 5 in Hg Vac, V_{max} = 57.5 ft/sec

1" Tube

Flow, acfm	13.8	27.6	41.3	
Vel., ft/sec	38.3	76.5	114.8	too high
ΔP, in Hg	0.2	0.9	1.9	

too high

1½" Tube

Flow, acfm	27.5	41.3	55.1	
Vel., ft/sec.	32.5	48.7	65	a bit high
ΔP, in Hg	0.1	0.2	0.4	

2" Tube

Flow, acfm	413	55.1	68.9	82.6	96.4	
Vel., ft/sec	29.6	39.4	49.3	59.1	68.9	high
ΔP, in Hg	~0.06	0.11	0.16	0.23	0.31	

Note: wt. flows in lb/hr from computer print-outs can be converted to SCFM per the following: —

$$SCFM = \frac{lb/hr}{60 \times 0.154}$$

JACOBS ENGINEERING GROUP INC.

ENGINEERING COMPUTATION SHEET

SUBJECT: SHEET: 5 OF 5
CLIENT: DATE: 4/21/92
COMPUTED BY: DK CHKD. BY: JOB: CONTRACT NO.: 05-6104-00

P= 10 in Hg vac, V_{max} = 60.6 fps

1" Tube

Flow, acfm	15.2	22.9	30.6	high
Vel., ft/sec	42.5	63.7	84.9	
ΔP, in Hg	0.3	0.6	~1.0	

1½" Tube

Flow, acfm	30.6	45.9	61.2	high
Vel., ft/sec	36.1	54.1	72.1	
ΔP, in Hg	0.1	0.2	0.4	

2" Tube

Flow, acfm	61.2	76.5	91.7	107	high
Vel., ft/sec	43.8	54.7	65.6	76.6	
ΔP, in Hg	0.1	0.2	0.26	0.34	

P= 15 in Hg Vac, V_{max} = 64.9 fps

1" tube

		high	high	
Flow, acfm	17.5	26.3	35.1	
Vel., ft/sec	48.7	73.1	97.4	
ΔP, in Hg	0.3	0.65	1.1	

1½" Tube

		high	high
Flow, acfm	35.1	52.6	70.1
Vel., ft/sec	41.4	62.0	82.7
ΔP, in Hg	0.1	0.3	0.5

2" Tube

Flow, acfm	70.1	87.7	105	high
Vel., ft/sec	50.2	62.7	75.3	
ΔP, in Hg	0.1	0.2	0.3	

MMMMMMMMMMMMMMMMMMMMMM VARIABLE SHEET MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM

St	Input	Name	Output	Unit	Comment
	100	F		LB/HR	FLOW RATE
		Q	103.04132	gpm	FLOW RATE
	.121	RHO		lb/ft^3	DENSITY
		SG	.00194097		SPECIFIC GRAVITY
	.015	VIS		cP	VISCOSITY
	1.049	d		INCHES	PIPE DIAMETER
		V	38.250251	ft/sec	VELOCITY
		Re	40165.237		REYNOLDS NUMBER
		f	.02649497		FRICTION FACTOR
		DP	.57949123	psi/100'	PRESSURE DROP

Pressure = 5 "Hg Vac

MMMMMMMMMMMMMMMMMMMMMM VARIABLE SHEET MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM

St	InputDDDD	NameDDD	OutputDDD	UnitDDDDD	CommentDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
	200	F		LB/HR	FLOW RATE
		Q	206.08264	gpm	FLOW RATE
	.121	RHO		lb/ft^3	DENSITY
		SG	.00194097		SPECIFIC GRAVITY
	.015	VIS		cP	VISCOSITY
	1.049	d		INCHES	PIPE DIAMETER
		V	76.500501	ft/sec	VELOCITY
		Re	80330.473		REYNOLDS NUMBER
		f	.02473971		FRICTION FACTOR
		DP	2.1644026	psi/100'	PRESSURE DROP

MMMMMMMMMMMMMMMMMMMMMM VARIABLE SHEET MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM

St	InputDDDD	NameDDD	OutputDDD	UnitDDDDD	CommentDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
	300	F		LB/HR	FLOW RATE
		Q	309.12397	gpm	FLOW RATE
	.121	RHO		lb/ft^3	DENSITY
		SG	.00194097		SPECIFIC GRAVITY
	.015	VIS		cP	VISCOSITY
	1.049	d		INCHES	PIPE DIAMETER
		V	114.75075	ft/sec	VELOCITY
		Re	120495.71		REYNOLDS NUMBER
		f	.02406291		FRICTION FACTOR
		DP	4.7366804	psi/100'	PRESSURE DROP

MMMMMMMMMMMMMMMMMMMMM VARIABLE SHEET MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM

St	Input	Name	Output	Unit	Comment
	200	F		LB/HR	FLOW RATE
		Q	206.08264	gpm	FLOW RATE
	.121	RHO		lb/ft^3	DENSITY
		SG	.00194097		SPECIFIC GRAVITY
	.015	VIS		cP	VISCOSITY
	1.61	d		INCHES	PIPE DIAMETER
		V	32.476073	ft/sec	VELOCITY
		Re	52339.545		REYNOLDS NUMBER
		f	.02419665		FRICTION FACTOR
		DP	.24856892	psi/100'	PRESSURE DROP

MMMMMMMMMMMMMMMMMMMMM VARIABLE SHEET MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM

St	InputDDDD	NameDDD	OutputDDD	UnitDDDDD	CommentDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
	300	F		LB/HR	FLOW RATE
		Q	309.12397	gpm	FLOW RATE
	.121	RHO		lb/ft^3	DENSITY
		SG	.00194097		SPECIFIC GRAVITY
	.015	VIS		cP	VISCOSITY
	1.61	d		INCHES	PIPE DIAMETER
		V	48.714109	ft/sec	VELOCITY
		Re	78509.317		REYNOLDS NUMBER
		f	.0230929		FRICTION FACTOR
		DP	.53376787	psi/100'	PRESSURE DROP

MMMMMMMMMMMMMMMMMMMMM VARIABLE SHEET MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM

St	InputDDDD	NameDDD	OutputDDD	UnitDDDDD	CommentDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
	400	F		LB/HR	FLOW RATE
		Q	412.16529	gpm	FLOW RATE
	.121	RHO		lb/ft^3	DENSITY
		SG	.00194097		SPECIFIC GRAVITY
	.015	VIS		cP	VISCOSITY
	1.61	d		INCHES	PIPE DIAMETER
		V	64.952145	ft/sec	VELOCITY
		Re	104679.09		REYNOLDS NUMBER
		f	.0224741		FRICTION FACTOR
		DP	.92349333	psi/100'	PRESSURE DROP

MMMMMMMMMMMMMMMMMMMMM VARIABLE SHEET MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM

St	InputDDDD	NameDDD	OutputDDD	UnitDDDDD	CommentDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
	300	F		LB/HR	FLOW RATE
		Q	309.12397	gpm	FLOW RATE
	.121	RHO		lb/ft^3	DENSITY
		SG	.00194097		SPECIFIC GRAVITY
	.015	VIS		cP	VISCOSITY
	2.067	d		INCHES	PIPE DIAMETER
		V	29.554632	ft/sec	VELOCITY
		Re	61151.427		REYNOLDS NUMBER
		f	.02301377		FRICTION FACTOR
		DP	.15250664	psi/100'	PRESSURE DROP

MMMMMMMMMMMMMMMMMMMMM VARIABLE SHEET MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM

St	InputDDDD	NameDDD	OutputDDD	UnitDDDDD	CommentDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
	400	F		LB/HR	FLOW RATE
		Q	412.16529	gpm	FLOW RATE
	.121	RHO		lb/ft^3	DENSITY
		SG	.00194097		SPECIFIC GRAVITY
	.015	VIS		cP	VISCOSITY
	2.067	d		INCHES	PIPE DIAMETER
		V	39.406176	ft/sec	VELOCITY
		Re	81535.236		REYNOLDS NUMBER
		f	.02221462		FRICTION FACTOR
		DP	.2617082	psi/100'	PRESSURE DROP

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St	Input	Name	Output	Unit	Comment
	500	F		LB/HR	FLOW RATE
		Q	515.20661	gpm	FLOW RATE
	.121	RHO		lb/ft^3	DENSITY
		SG	.00194097		SPECIFIC GRAVITY
	.015	VIS		cP	VISCOSITY
	2.067	d		INCHES	PIPE DIAMETER
		V	49.257721	ft/sec	VELOCITY
		Re	101919.05		REYNOLDS NUMBER
		f	.02168823		FRICTION FACTOR
		DP	.39922946	psi/100'	PRESSURE DROP

MMMMMMMMMMMMMMMMMMMMM VARIABLE SHEET MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM

St	InputDDDD	NameDDD	OutputDDD	UnitDDDDD	CommentDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
	600	F		LB/HR	FLOW RATE
		Q	618.24793	gpm	FLOW RATE
	.121	RHO		lb/ft^3	DENSITY
		SG	.00194097		SPECIFIC GRAVITY
	.015	VIS		cP	VISCOSITY
	2.067	d		INCHES	PIPE DIAMETER
		V	59.109265	ft/sec	VELOCITY
		Re	122302.85		REYNOLDS NUMBER
		f	.02131314		FRICTION FACTOR
		DP	.56494804	psi/100'	PRESSURE DROP

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St	InputDDDD	NameDDD	OutputDDD	UnitDDDDD	CommentDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
	700	F		LB/HR	FLOW RATE
		Q	721.28926	gpm	FLOW RATE
	.121	RHO		lb/ft^3	DENSITY
		SG	.00194097		SPECIFIC GRAVITY
	.015	VIS		cP	VISCOSITY
	2.067	d		INCHES	PIPE DIAMETER
		V	68.960809	ft/sec	VELOCITY
		Re	142686.66		REYNOLDS NUMBER
		f	.02103143		FRICTION FACTOR
		DP	.758793	psi/100'	PRESSURE DROP

MMMMMMMMMMMMMMMMMMMMM VARIABLE SHEET MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM

St	InputDDDD	NameDDD	OutputDDD	UnitDDDDD	CommentDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
	100	F		LB/HR	FLOW RATE
		Q	114.38532	gpm	FLOW RATE
	.109	RHO		lb/ft^3	DENSITY
		SG	.00174848		SPECIFIC GRAVITY
	.015	VIS		cP	VISCOSITY
	1.049	d		INCHES	PIPE DIAMETER
		V	42.461287	ft/sec	VELOCITY
		Re	40165.237		REYNOLDS NUMBER
		f	.02649497		FRICTION FACTOR
		DP	.64328843	psi/100'	PRESSURE DROP

Press = 10" Hg Vac

MMMMMMMMMMMMMMMMMMMMMMM VARIABLE SHEET MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM

St	InputDDDD	NameDDD	OutputDDD	UnitDDDDD	CommentDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
	150	F		LB/HR	FLOW RATE
		Q	171.57798	gpm	FLOW RATE
	.109	RHO		lb/ft^3	DENSITY
		SG	.00174848		SPECIFIC GRAVITY
	.015	VIS		cP	VISCOSITY
	1.049	d		INCHES	PIPE DIAMETER
		V	63.691931	ft/sec	VELOCITY
		Re	60247.855		REYNOLDS NUMBER
		f	.02536483		FRICTION FACTOR
		DP	1.3856605	psi/100'	PRESSURE DROP

MMMMMMMMMMMMMMMMMMMMM VARIABLE SHEET MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM

St	InputDDDD	NameDDD	OutputDDD	UnitDDDDD	CommentDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
	200	F		LB/HR	FLOW RATE
		Q	228.77064	gpm	FLOW RATE
	.109	RHO		lb/ft^3	DENSITY
		SG	.00174848		SPECIFIC GRAVITY
	.015	VIS		cP	VISCOSITY
	1.049	d		INCHES	PIPE DIAMETER
		V	84.922575	ft/sec	VELOCITY
		Re	80330.473		REYNOLDS NUMBER
		f	.02473971		FRICTION FACTOR
		DP	2.4026854	psi/100'	PRESSURE DROP

MMMMMMMMMMMMMMMMMMMMMM VARIABLE SHEET MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM

St	InputDDDD	NameDDD	OutputDDD	UnitDDDDD	CommentDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
	300	F		LB/HR	FLOW RATE
		Q	343.15596	gpm	FLOW RATE
	.109	RHO		lb/ft^3	DENSITY
		SG	.00174848		SPECIFIC GRAVITY
	.015	VIS		cP	VISCOSITY
	1.049	d		INCHES	PIPE DIAMETER
		V	127.38386	ft/sec	VELOCITY
		Re	120495.71		REYNOLDS NUMBER
		f	.02406291		FRICTION FACTOR
		DP	5.2581498	psi/100'	PRESSURE DROP

MMMMMMMMMMMMMMMMMMMMM VARIABLE SHEET MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM

St	InputDDDD	NameDDD	OutputDDD	UnitDDDDD	CommentDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
	200	F		LB/HR	FLOW RATE
		Q	228.77064	gpm	FLOW RATE
	.109	RHO		lb/ft^3	DENSITY
		SG	.00174848		SPECIFIC GRAVITY
	.015	VIS		cP	VISCOSITY
	1.61	d		INCHES	PIPE DIAMETER
		V	36.05142	ft/sec	VELOCITY
		Re	52339.545		REYNOLDS NUMBER
		f	.02419665		FRICTION FACTOR
		DP	.27593431	psi/100'	PRESSURE DROP

MMMMMMMMMMMMMMMMMMMMM VARIABLE SHEET MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM

St	InputDDDD	NameDDD	OutputDDD	UnitDDDDD	CommentDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
	300	F		LB/HR	FLOW RATE
		Q	343.15596	gpm	FLOW RATE
	.109	RHO		lb/ft^3	DENSITY
		SG	.00174848		SPECIFIC GRAVITY
	.015	VIS		cP	VISCOSITY
	1.61	d		INCHES	PIPE DIAMETER
		V	54.07713	ft/sec	VELOCITY
		Re	78509.317		REYNOLDS NUMBER
		f	.0230929		FRICTION FACTOR
		DP	.59253131	psi/100'	PRESSURE DROP

MMMMMMMMMMMMMMMMMMMMM VARIABLE SHEET MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM

St	InputDDDD	NameDDD	OutputDDD	UnitDDDDD	CommentDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
	400	F		LB/HR	FLOW RATE
		Q	457.54128	gpm	FLOW RATE
	.109	RHO		lb/ft^3	DENSITY
		SG	.00174848		SPECIFIC GRAVITY
	.015	VIS		cP	VISCOSITY
	1.61	d		INCHES	PIPE DIAMETER
		V	72.10284	ft/sec	VELOCITY
		Re	104679.09		REYNOLDS NUMBER
		f	.0224741		FRICTION FACTOR
		DP	1.0251623	psi/100'	PRESSURE DROP

MMMMMMMMMMMMMMMMMMMMM VARIABLE SHEET MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM

St	Input	Name	Output	Unit	Comment
	700	F		LB/HR	FLOW RATE
		Q	800.69725	gpm	FLOW RATE
	.109	RHO		lb/ft^3	DENSITY
		SG	.00174848		SPECIFIC GRAVITY
	.015	VIS		cP	VISCOSITY
	2.067	d		INCHES	PIPE DIAMETER
		V	76.552825	ft/sec	VELOCITY
		Re	142686.66		REYNOLDS NUMBER
		f	.02103143		FRICTION FACTOR
		DP	.84232985	psi/100'	PRESSURE DROP

MMMMMMMMMMMMMMMMMMMMM VARIABLE SHEET MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM

St	InputDDDD	NameDDD	OutputDDD	UnitDDDDD	CommentDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
	500	F		LB/HR	FLOW RATE
		Q	571.92661	gpm	FLOW RATE
	.109	RHO		lb/ft^3	DENSITY
		SG	.00174848		SPECIFIC GRAVITY
	.015	VIS		cP	VISCOSITY
	2.067	d		INCHES	PIPE DIAMETER
		V	54.680589	ft/sec	VELOCITY
		Re	101919.05		REYNOLDS NUMBER
		f	.02168823		FRICTION FACTOR
		DP	.44318133	psi/100'	PRESSURE DROP

MMMMMMMMMMMMMMMMMMMMM VARIABLE SHEET MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM

St	InputDDDD	NameDDD	OutputDDD	UnitDDDDD	CommentDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
	400	F		LB/HR	FLOW RATE
		Q	457.54128	gpm	FLOW RATE
	.109	RHO		lb/ft^3	DENSITY
		SG	.00174848		SPECIFIC GRAVITY
	.015	VIS		cP	VISCOSITY
	2.067	d		INCHES	PIPE DIAMETER
		V	43.744471	ft/sec	VELOCITY
		Re	81535.236		REYNOLDS NUMBER
		f	.02221462		FRICTION FACTOR
		DP	.29052012	psi/100'	PRESSURE DROP

MMMMMMMMMMMMMMMMMMMMM VARIABLE SHEET MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM

St	InputDDDD	NameDDD	OutputDDD	UnitDDDDD	CommentDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
	600	F		LB/HR	FLOW RATE
		Q	686.31193	gpm	FLOW RATE
	.109	RHO		lb/ft^3	DENSITY
		SG	.00174848		SPECIFIC GRAVITY
	.015	VIS		cP	VISCOSITY
	2.067	d		INCHES	PIPE DIAMETER
		V	65.616707	ft/sec	VELOCITY
		Re	122302.85		REYNOLDS NUMBER
		f	.02131314		FRICTION FACTOR
		DP	.62714416	psi/100'	PRESSURE DROP

MMMMMMMMMMMMMMMMMMMMMM VARIABLE SHEET MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM

St	InputDDDD	NameDDD	OutputDDD	UnitDDDDD	CommentDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
	700	F		LB/HR	FLOW RATE
		Q	918.69474	gpm	FLOW RATE
	.095	RHO		lb/ft^3	DENSITY
		SG	.0015239		SPECIFIC GRAVITY
	.015	VIS		cP	VISCOSITY
	2.067	d		INCHES	PIPE DIAMETER
		V	87.834293	ft/sec	VELOCITY
		Re	142686.66		REYNOLDS NUMBER
		f	.02103143		FRICTION FACTOR
		DP	.96646267	psi/100'	PRESSURE DROP

Press = 15" Hg Vac

MMMMMMMMMMMMMMMMMMMMMM VARIABLE SHEET MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM

St	InputDDDD	NameDDD	OutputDDD	UnitDDDDD	CommentDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
	600	F		LB/HR	FLOW RATE
		Q	787.45263	gpm	FLOW RATE
	.095	RHO		lb/ft^3	DENSITY
		SG	.0015239		SPECIFIC GRAVITY
	.015	VIS		cP	VISCOSITY
	2.067	d		INCHES	PIPE DIAMETER
		V	75.286537	ft/sec	VELOCITY
		Re	122302.85		REYNOLDS NUMBER
		f	.02131314		FRICTION FACTOR
		DP	.7195654	psi/100'	PRESSURE DROP

MMMMMMMMMMMMMMMMMMMMM VARIABLE SHEET MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM

St	InputDDDD	NameDDD	OutputDDD	UnitDDDDD	CommentDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
	500	F		LB/HR	FLOW RATE
		Q	656.21053	gpm	FLOW RATE
	.095	RHO		lb/ft^3	DENSITY
		SG	.0015239		SPECIFIC GRAVITY
	.015	VIS		cP	VISCOSITY
	2.067	d		INCHES	PIPE DIAMETER
		V	62.738781	ft/sec	VELOCITY
		Re	101919.05		REYNOLDS NUMBER
		f	.02168823		FRICTION FACTOR
		DP	.50849227	psi/100'	PRESSURE DROP

MMMMMMMMMMMMMMMMMMMMMM VARIABLE SHEET MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM

St	InputDDDD	NameDDD	OutputDDD	UnitDDDDD	CommentDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
	400	F		LB/HR	FLOW RATE
		Q	524.96842	gpm	FLOW RATE
	.095	RHO		lb/ft^3	DENSITY
		SG	.0015239		SPECIFIC GRAVITY
	.015	VIS		cP	VISCOSITY
	2.067	d		INCHES	PIPE DIAMETER
		V	50.191025	ft/sec	VELOCITY
		Re	81535.236		REYNOLDS NUMBER
		f	.02221462		FRICTION FACTOR
		DP	.33333361	psi/100'	PRESSURE DROP

MMMMMMMMMMMMMMMMMMMMM VARIABLE SHEET MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM

St	InputDDDD	NameDDD	OutputDDD	UnitDDDDD	CommentDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
	400	F		LB/HR	FLOW RATE
		Q	524.96842	gpm	FLOW RATE
	.095	RHO		lb/ft^3	DENSITY
		SG	.0015239		SPECIFIC GRAVITY
	.015	VIS		cP	VISCOSITY
	1.61	d		INCHES	PIPE DIAMETER
		V	82.728522	ft/sec	VELOCITY
		Re	104679.09		REYNOLDS NUMBER
		f	.0224741		FRICTION FACTOR
		DP	1.1762389	psi/100'	PRESSURE DROP

MMMMMMMMMMMMMMMMMMMMM VARIABLE SHEET MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM

St	InputDDDD	NameDDD	OutputDDD	UnitDDDDD	CommentDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
	300	F		LB/HR	FLOW RATE
		Q	393.72632	gpm	FLOW RATE
	.095	RHO		lb/ft^3	DENSITY
		SG	.0015239		SPECIFIC GRAVITY
	.015	VIS		cP	VISCOSITY
	1.61	d		INCHES	PIPE DIAMETER
		V	62.046391	ft/sec	VELOCITY
		Re	78509.317		REYNOLDS NUMBER
		f	.0230929		FRICTION FACTOR
		DP	.67985171	psi/100'	PRESSURE DROP

MMMMMMMMMMMMMMMMMMMM VARIABLE SHEET MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM

St	InputDDDD	NameDDD	OutputDDD	UnitDDDDD	CommentDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
	200	F		LB/HR	FLOW RATE
		Q	262.48421	gpm	FLOW RATE
	.095	RHO		lb/ft^3	DENSITY
		SG	.0015239		SPECIFIC GRAVITY
	.015	VIS		cP	VISCOSITY
	1.61	d		INCHES	PIPE DIAMETER
		V	41.364261	ft/sec	VELOCITY
		Re	52339.545		REYNOLDS NUMBER
		f	.02419665		FRICTION FACTOR
		DP	.31659831	psi/100'	PRESSURE DROP

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St	Input	Name	Output	Unit	Comment
	300	F		LB/HR	FLOW RATE
		Q	393.72632	gpm	FLOW RATE
	.095	RHO		lb/ft^3	DENSITY
		SG	.0015239		SPECIFIC GRAVITY
	.015	VIS		cP	VISCOSITY
	1.049	d		INCHES	PIPE DIAMETER
		V	146.15622	ft/sec	VELOCITY
		Re	120495.71		REYNOLDS NUMBER
		f	.02406291		FRICTION FACTOR
		DP	6.0330351	psi/100'	PRESSURE DROP

MMMMMMMMMMMMMMMMMMMMMM VARIABLE SHEET MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM

St	Input	Name	Output	Unit	Comment
	200	F		LB/HR	FLOW RATE
		Q	262.48421	gpm	FLOW RATE
	.095	RHO		lb/ft^3	DENSITY
		SG	.0015239		SPECIFIC GRAVITY
	.015	VIS		cP	VISCOSITY
	1.049	d		INCHES	PIPE DIAMETER
		V	97.43748	ft/sec	VELOCITY
		Re	80330.473		REYNOLDS NUMBER
		f	.02473971		FRICTION FACTOR
		DP	2.7567654	psi/100'	PRESSURE DROP

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St	Input	Name	Output	Unit	Comment
	150	F		LB/HR	FLOW RATE
		Q	196.86316	gpm	FLOW RATE
	.095	RHO		lb/ft^3	DENSITY
		SG	.0015239		SPECIFIC GRAVITY
	.015	VIS		cP	VISCOSITY
	1.049	d		INCHES	PIPE DIAMETER
		V	73.07811	ft/sec	VELOCITY
		Re	60247.855		REYNOLDS NUMBER
		f	.02536483		FRICTION FACTOR
		DP	1.5898631	psi/100'	PRESSURE DROP

MMMMMMMMMMMMMMMMMMMMM VARIABLE SHEET MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM

St	InputDDDD	NameDDD	OutputDDD	UnitDDDDD	CommentDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
	100	F		LB/HR	FLOW RATE
		Q	131.24211	gpm	FLOW RATE
	.095	RHO		lb/ft^3	DENSITY
		SG	.0015239		SPECIFIC GRAVITY
	.015	VIS		cP	VISCOSITY
	1.049	d		INCHES	PIPE DIAMETER
		V	48.71874	ft/sec	VELOCITY
		Re	40165.237		REYNOLDS NUMBER
		f	.02649497		FRICTION FACTOR
		DP	.73808883	psi/100'	PRESSURE DROP